RCRA Facility Investigation – Remedial Investigation/ Corrective Measures Study – Feasibility Study Report for the Rocky Flats Environmental Technology Site

Section 2.0
Physical Characteristics of the Study Area

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for the U.S. Department of Energy

June 2006

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2.0 PHYSICAL CHARACTERISTICS OF THE STUDY AREA

Colorado Department of Public Health and Environment (CDPHE) guidance states that the site setting describes not only the physical features of the site, but also identifies the nearby cultural and environmental populations that could be potentially impacted by a release from the facility. Surface characteristics include both natural and manmade structures on and adjacent to the site, nearby cultural populations, and all relevant flora and fauna populations. It is important to evaluate natural features and manmade structures, such as drainage systems, local topography, utilities, surface water bodies, easements, and locations of buildings, because these features can influence the migration of contaminants and restrict access to portions of the site during remedial efforts. Subsurface characteristics include the hydrologic and geologic properties of the ground beneath the facility and surrounding properties. This information is used in conjunction with other site setting information in evaluating contaminant migration pathways and establishing potential exposure scenarios (CDPHE 2002).

Under CERCLA, data on physical characteristics of the site and surrounding areas should be collected to the extent necessary to define potential transport pathways and receptor populations and provide sufficient engineering data for development and screening of remedial alternatives. Information normally needed can be categorized as surface features (including natural and artificial features), geology, soils, surface water hydrology, hydrogeology, meteorology, human populations, land uses, and ecology (EPA 1988).

2.1 Introduction

This section provides a summary of the physical characteristics of the Rocky Flats Environmental Technology Site (RFETS or site), which was completed in accordance with the Final Work Plan for the Development of the Remedial Investigation and Feasibility Study Report (RI/FS Work Plan) (DOE 2002) Task 7. The RI/FS Work Plan states that the physical characteristics of the study area will summarize the physical characteristics of the site, including surface features, meteorology, surface water hydrology, geology, soil, hydrologeology, demography and land use, and ecology (DOE 2002). The study area addressed in this section includes the Industrial Area (IA) and Buffer Zone (BZ) Operable Units (OUs) at RFETS. The study area also includes areas adjacent to RFETS, depending upon the specific characteristic being evaluated. Information presented in this section is provided to help characterize the physical features at RFETS to support the analysis and design of potential response actions evaluated in Section 11.0.

2.2 Surface Features

The site is located at the interface of the Great Plains and Rocky Mountains. Approximately 2 miles west of the RFETS western boundary, the foothills of the Front Range rise sharply above the lower elevations of the plains. The higher-elevation areas west of RFETS are characterized by rugged terrain and relatively sparse human population. In contrast, the plains east of RFETS are characterized by relatively gentle topography and higher-population density associated with the greater Denver metropolitan area.

The western portion of RFETS is located on a broad, relatively flat pediment that slopes eastward from the foothills. The pediment is capped by unconsolidated surficial deposits. On the eastern portion of RFETS, the pediment surface is dissected by stream valleys that trend generally from west to east. The valleys cut into the underlying bedrock in some locations, although in most places bedrock is located beneath colluvium that has collected along the valley slopes. Elevations at RFETS range from approximately 6,190 feet (ft) above mean sea level (MSL) on the western portion of the pediment to approximately 5,600 ft above MSL in the southeastern corner of the site.

The primary topographic features at RFETS are the Rock Creek, Walnut Creek, and Woman Creek drainages that traverse the site and flow generally from west to east (Figure 2.1). Sixteen named retention ponds exist throughout RFETS. These include nine ponds on North and South Walnut Creeks, two ponds in the Woman Creek drainage, one pond downgradient from the site of the Present Landfill, two ponds in the Rock Creek drainage, and two ponds on Smart Ditch. In addition to the ponds, other manmade surface water features at RFETS include several drainage ditches that cross the site, including the South Interceptor Ditch (SID), Woman Creek Bypass, McKay Ditch, Upper Church Ditch, and Smart Ditch (see Section 2.5).

RFETS is vegetated with five general plant communities. These include the mixed mesic grassland and xeric tallgrass prairie, which are the dominant plant communities. Wetlands, riparian woodlands, and tall upland shrublands are less dominant plant communities. A detailed discussion of the various plant communities is provided in Section 2.9.1.

Site accelerated remedial actions resulted in removal of buildings, except for the former east and west vehicle inspection sheds. Surface pavement has been removed. For a discussion of remaining subsurface foundational elements, see Section 2.3. Other site activities resulted in some surface recontouring and revegetation of the former IA, after removal of parking lots and other surface infrastructure features, as necessary, to provide a stable land surface consistent with the end use of RFETS as a wildlife refuge.

The management of site stormwater in the former IA, at the completion of accelerated actions, including building demolitions, was to allow surface water to flow as non-channelized flow following the existing contours of the site. An overall goal was to disturb as little of the existing surface as possible while maintaining dispersed non-channelized flow. A design criterion for the site drainage was to maintain soil and slope stability by minimizing erosion. Revegetation and erosion mats and/or hydromulching were utilized to control erosion in areas of disturbed soil and sloping surfaces.

Five functional channels were configured to also minimize soil disturbance and were generally placed in areas of existing major surface water drainage features. Erosion was controlled in the functional channels by armoring the entire length of the channel with riprap or erosion matting and revegetation. Each of the five functional channels was designed to convey the 100-year storm event as follows:

- Functional Channel (FC)-1: FC-1 drains the northwestern corner of the former IA by a combination of an existing vegetated channel and a new channel through the soil borrow area directly west of the former Building 371 area. The upstream portion of FC-1 was an existing surface water feature. FC-1 is approximately 2,000 ft long and drains an area of 48 acres with a peak flow capacity of 76 cubic feet per second (cfs).[1]

- FC-2: FC-2 drains an area between and south of the former Buildings 371 and 771 areas by a combination of an existing vegetated channel and a new channel upstream of the existing channel. Much of FC-2 was an existing surface water drainage feature and located in the flowline of large-diameter culverts that were removed in most cases, although one culvert does remain operational. Several culverts in the upstream portion of the FC-2 watershed (south and east of the former Building 371 site) were plugged on the ends and not removed. A wetland area was constructed downstream of the existing channel before FC-2 flows into FC-3. FC-2 is approximately 1,800 ft long and drains an area of 51 acres with a peak flow capacity of 72 cfs.

- FC-3: FC-3 drains the northern side of the former IA and receives flow from FC-2. FC-3 is located at an existing surface water feature and in the flowline of large-diameter culverts that were removed. Several storm drains were plugged on the ends and left in place in the FC-3 watershed, including near the former Building 771/774 area, under the former Building 771 parking lot, and in the area between where the historical Solar Evaporation Ponds (SEPs) 207C and 207A were formerly located. FC-3 is approximately 1,200 ft long and drains an area of 197 acres with a peak flow capacity of 264 cfs.

- FC-4: FC-4 drains the middle and southern portion of the former IA. FC-4 is located at an existing surface water feature and in the flowline of several large-diameter culverts that were removed. Several culverts were left in place with plugged ends in the FC-4 watershed, including east and west of the former Building 460 area, and south of the former Building 460 and 444 areas. A wetland was constructed in FC-4 in an existing flat area of the channel. FC-4 is approximately 3,300 ft long and drains an area of 242 acres with a peak flow capacity of 277 cfs.

- FC-5: FC-5 drains the southeastern corner of the former IA and conveys water into FC-4. FC-5 is the combination of an existing vegetated channel and a new channel. A portion of FC-5 is an existing surface water feature. The new portion of the FC generally follows the flowline of a large-diameter culvert that was removed. The one culvert in the FC-5 watershed that was left in place and plugged on the ends is near the historical Mound (IHSS 113) remediation site.

[1] The peak flow rates for the functional channels are based on a 100-year design storm.

FC-5 is approximately 1,400 ft long and drains an area of 24 acres with a peak flow capacity of 37 cfs.

This work was completed as part of a series of best management practices (BMPs) and was generally guided by the Land Configuration drawings (K-H 2004a) and the Environmental Assessment, Pond and Land Configuration DOE/EA – 1492 (DOE 2004a). RFETS surface features after accelerated actions are presented on Figure 2.2. Overland flow directions and FC watershed delineations are presented on Figure 2.3.

Other manmade features of the site include protective covers constructed under approved Interim Measure/Interim Remedial Action (IM/IRA) decision documents at two landfills, the Original Landfill and Present Landfill, which were used for historic site operations. The Original Landfill, located in the southwestern corner of the IA OU, has a soil cover layer with a minimum thickness of 2 ft. The soil cover is engineered to promote surface water runoff while minimizing erosion, reduce surface water ponding, increase overall slope stability, and provide for suitable vegetation (DOE 2004b). At the Present Landfill, located north of the IA OU, a cover was constructed to comply with closure requirements of the Resource Conservation and Recovery Act (RCRA) for minimizing infiltration and erosion. The Present Landfill cover consists of a soil cover, geosynthetic clay liner, flexible membrane liner, geocomposite drainage layer, cushion layer, cobble layer, and soil cover layer (DOE 2004c). Additionally, surface vegetation will be established on this soil layer to enhance resistance to surface erosion, prevent intrusion of noxious weeds and burrowing animals, and provide an aesthetic appearance to the cover, using appropriate native seed mixes.

Several public utility corridors have historically been located within the site boundaries, including low- and high-pressure natural gas pipelines, electric transmission lines, and telecommunication lines. These utilities are expected to remain as long as the utility easement or right-of-way is needed. Figure 2.4 presents a map of existing utility easements. The Rocky Flats National Wildlife Refuge (Refuge) Act provides that land may be made available for transportation improvements along Indiana Street along the eastern RFETS boundary. All other land transfers are prohibited by the Refuge Act.

2.3 Subsurface Features

Between the ground surface and 3 ft below grade, essentially all structures have been removed, with the exception of utility lines less than 2 inches in diameter, three groundwater collection and treatment systems that serve an ongoing function, and the Present Landfill seep collection and treatment system. The groundwater and seep treatment systems are listed below and are shown on Figure 2.2:

- Solar Ponds Plume Treatment System (SPPTS);
- Mound Site Plume Treatment System (MSPTS);
- East Trenches Plume Treatment System (ETPTS); and

- Present Landfill Seep Treatment System.

At depths greater than 3 ft below grade, some subsurface structures remain in place. These include slabs, tunnels, and building foundations (including in some areas caissons or grade beams) (Figure 2.5); sewer lines and water lines (Figure 2.6); culverts, foundation drains, and storm drains (Figure 2.7); and valve vaults and process waste lines (both Original Process Waste Lines [OPWL] and New Process Waste Lines [NPWL]) (Figure 2.8).

Some subsurface features may contain residual contamination. In particular, these features include slabs and building foundations, as well as valve vaults and process waste lines.

For slabs and building foundations with contamination, see Figure 2.5 and building-specific closeout reports, as referenced in Table 1.5, for details. Portions of the former Buildings 371/374 basement and subbasement slab/walls, former Building 730 basement slab, former Building 771 first and second floor slabs and walls, former Building 771C slab, former Building 774 first and second floor slab/walls, and the tunnel between former Buildings 771 and 776 have residual americium-241 and plutonium-239/240 contamination. The remaining contamination in these former building slabs, walls, and tunnel is fixed within the building concrete matrix after concrete surface removal by mechanical decontamination was performed to the extent practical. In addition, portions of former Building 991 floor slabs have residual nonfriable asbestos contamination.

For valve vaults and process waste lines with contamination, see Figure 2.8 and closeout reports for the OPWL and NPWL, as referenced in Table 1.4. It is noted that a majority of OPWL remaining in the subsurface is contaminated, while only a portion of NPWL is contaminated. Some portions of the remaining OPWL have residual uranium-234, uranium-235, and uranium-238, americium-241, and plutonium-239/240 contamination. Some portions of the remaining NPWL and four NPWL valve vaults have residual uranium-234, uranium-235, and uranium-238, americium-241, and plutonium-239/240 contamination. The remaining portions of OPWL and NPWL were disrupted at numerous excavation locations and filled with grout to the extent possible.

Fence posts and utility poles in place on September 19, 2003, except those in Preble's meadow jumping mouse (PMJM) habitat areas, have been removed. In the PMJM areas, posts and poles were cut off as close to ground level as possible. Posts and poles previously cut (prior to September 19, 2003) at ground level remain and are not shown on Figure 2.5. If a post or pole broke at or below ground surface while it was being pulled, the remaining section was left and is not shown on Figure 2.5 through Figure 2.8.

This information is a reasonably representative depiction of known important structures and infrastructure components and is not intended as a definitive or all-inclusive mapping of everything that might be encountered in the subsurface. There are likely some items left in the subsurface over the more than 50-year history of RFETS that cannot be mapped because the locations are not known.

2.4 Geology

RFETS is situated approximately 2 miles east of the Front Range of Colorado on the western margin of the Colorado Piedmont section of the Great Plains Physiographic Province (Spencer 1961). The geologic history of the Colorado Rocky Mountain region, which includes the site area, has been summarized by Haun and Kent (1965). Several comprehensive site-specific studies have been undertaken to characterize the local geology and hydrogeology at RFETS (Hurr 1976; EG&G 1991, 1995a, 1995b). In addition, a large amount of lithologic and stratigraphic information has been obtained for RFETS from multiple sources. These include interpretation of aerial photographs, field geologic mapping, coal and aggregate mine development, petroleum exploration, and the completion of approximately 2,000 on-site boreholes and monitoring wells. A brief summary of results from historic investigations is presented in the following sections. The effects of the geochemistry on the environmental fate and transport of an analyte is provided in Section 8.0.

2.4.1 Stratigraphy

The stratigraphic sequence that underlies the site extends in age from the crystalline Precambrian gneiss, schist, and granitoids at 3,000 ft below MSL to the unconsolidated Quaternary deposits at the surface approximately 6,000 ft above MSL. A generalized stratigraphic column for the Rocky Flats area is shown on Figure 2.9 (Leroy and Weimer 1971).

The Pierre Shale and Fox Hills Sandstone underlie the site, with the latter exposed in quarries along the western edge of the site. The Laramie and Arapahoe Formations are exposed at the surface or underlie the site. Unconsolidated surficial deposits (for example, the Rocky Flats Alluvium [RFA] and the Verdos terrace alluvium) unconformably overlie bedrock. The unconsolidated surficial deposits, combined with the weathered portion of subcropping bedrock formations, form the upper hydrostratigraphic unit (UHSU).[2] Because of the wide extent of unconsolidated surficial materials beneath the IA and eastern BZ OUs, and relatively high hydraulic conductivity compared to that of the underlying weathered claystone, the unconsolidated portion of the UHSU is the primary influence on groundwater flow and contaminant transport at the site.

2.4.2 Unconsolidated Surficial Deposits

Based on local mapping (Hurr 1976; EG&G 1995a; USGS 1996), the unconsolidated surficial deposits that cover the pediment and adjacent watersheds proximal to the IA OU consist of the RFA, Valley Fill Alluvium (VFA), and colluvium that unconformably

[2] Pursuant to Colorado Water Quality Control Regulation 42.5(7), the UHSU is the uppermost layer of groundwater incorporating any aquifer or other zone of groundwater occurrence that is first encountered beneath the ground surface and includes all saturated geologic formations, unconsolidated alluvium and colluvium, and hydraulically connected zones in bedrock. Pursuant to Colorado Water Quality Control Regulation 42.7(1)(a), the UHSU includes the unconsolidated Quarternary and RFA, colluvium and Valley Fill Alluvium (VFA), and weathered claystone and hydraulically connected sandstone bedrock of the Arapahoe and upper Laramie Formations.

overlie bedrock. Various other younger unconsolidated alluvial deposits, such as the Piney Creek Alluvium (EG&G 1995a; USGS 1996), occur topographically below the RFA in the RFETS drainages. In addition, artificial fill material is found locally throughout the IA OU, and landslide and slump deposits are common on slopes in the BZ OU (EG&G 1995a) (Figure 2.10). The surface geology at RFETS is shown on Figure 2.11.

2.4.2.1 RFA

The youngest areally-extensive stratigraphic unit at RFETS is the early Pleistocene RFA. The RFA was deposited by intermittent braided streams and debris flows. Deposition took place on the pediment within a coalescing alluvial fan/braided stream system. Coarse gravel and cobbles were most likely deposited in channels by debris flows. Sand and fine gravel were deposited in channels and along banks, forming natural levees, while silt and clay would commonly be found on floodplains. The RFA occurs above the erosional bedrock surface and consists of generally poorly sorted, poorly stratified gravel, sand, cobbles, silt, and clay. The thickness of the RFA decreases from west to east, and ranges from slightly more than 100 ft to less than 10 ft. This is particularly important in the eastern IA and BZ OUs where the RFA is thinner or nonexistent. In those areas, the UHSU groundwater flows through weathered bedrock, instead of the RFA, and therefore moves at a much slower velocity compared with RFA flow.

The coarse clastic materials (boulders and cobbles) were derived primarily from the Precambrian igneous and metamorphic rocks that crop out in Coal Creek Canyon, approximately 2 miles west of RFETS. Less common source rocks are the steeply eastward-dipping sedimentary formations exposed at the mouth of Coal Creek Canyon.

2.4.2.2 Colluvium

Colluvium occurs on the hillslopes descending into drainages at RFETS. This material is derived from the RFA and underlying weathered bedrock, and has a hydraulic conductivity intermediate to the hydraulic conductivities of those two formations. Colluvial material consists of unconsolidated clay with silty clay, sandy clay, and gravel layers. Occasional dark-yellowish-orange iron staining is present in colluvium consisting of reworked bedrock.

<u>Landslide and Slump Deposits</u>

Landslide and slump deposits have been identified in nearly all of the drainages at RFETS (EG&G 1995a; USGS 1996). These occur primarily in the upper bedrock claystones and involve downward and outward movement along rotational slip planes. At RFETS, landslides and slumps are recognized by a curved scarp at the top, a coherent mass of material downslope that has been rotated back toward the slip plane, and hummocky topography at the base. Older, weathered landslide and slump deposits are expressed in weakly consolidated, grass-covered slopes as bulges or low wavelike swells (EG&G 1995a; USGS 1996). Several distinct landslide and bedrock slump-blocks have been mapped above and along the banks of Walnut and Woman Creeks (EG&G 1995a; USGS 1996). These deposits can be up to 35 ft thick but are generally relatively shallow.

2.4.2.3 VFA

VFA occurs in all the major drainages at RFETS and consists of unconsolidated, poorly sorted sand, gravel, and pebbles in a silty clay matrix. Shroba and Carrara recognized two stages of VFA: Piney Creek and Post-Piney Creek Alluvium (USGS 1996). The Piney Creek Alluvium forms low terraces approximately 3 to 6 ft above modern stream level, and contains calcium carbonate veinlets and locally one or more buried soil horizons. The Post-Piney Creek Alluvium forms modern stream channels and floodplains, and does not contain secondary calcium carbonate.

2.4.2.4 Caliche

Local intervals of the unconsolidated surficial deposits may contain caliche, ranging from 25 to 80 percent. Caliche, which is generally calcium carbonate but may consist of magnesium carbonate, silica, or gypsum, forms by evaporation of vadose zone water. Early stages of caliche formation may produce either a powdery granular calcite or development of indurated nodules, termed “calcrete” (Blatt et al. 1980). Activities related to construction and site development have removed caliche deposits from some areas, particularly within the IA OU.

2.4.2.5 Artificial Fill

Artificial fill is a term that applies to material that has been deposited through human activities rather than geologic processes. Included as artificial fill are earthen dams and berms, railroad embankments, roads, landfills, and backfill related to RFETS development or closure, as well as the mine dumps associated with quarry operations on the west side of the site. Many deposits of artificial fill are merely composed of reworked RFA, weathered claystone, and/or other original materials, which have been displaced from their original position and redistributed. Other deposits are not of a geologic origin, such as sanitary wastes in landfills and concrete rubble in basements. Deposits of artificial fill at RFETS are most commonly less than 10 ft thick, although they may exceed 30 ft thick (for example, dams and landfills) (EG&G 1995a).

2.4.3 Bedrock Deposits

An unconformity, representing a depositional hiatus of greater than 60 million years, separates the Arapahoe and Laramie Formations from the overlying unconsolidated surficial deposits. The bedrock surface that makes up the unconformity comprises the irregular, undulating surface of the pediment, controlled in part by stream erosion/incision and subsequent deposition of the RFA. Incised channels in the bedrock surface represent important local preferential groundwater flow paths (EG&G 1995b).

2.4.3.1 Arapahoe Formation

The Arapahoe Formation is mainly composed of claystone and silty claystone, with lenticular sandstone bodies in the basal portion of the formation, and is generally less than 50 ft thick at RFETS (EG&G 1995a). The depth of the contact between the Arapahoe Formation and the underlying Laramie Formation is generally less than 100 ft below ground surface in the RFETS area. In many areas, the Arapahoe Formation is entirely absent, having been removed by erosion.

<u>Arapahoe Formation Sandstones</u>

The basal sandstones in the Arapahoe Formation (referred to as the No. 1 Sandstone) are poorly to moderately sorted, subangular to subrounded, clayey, silty, very fine-grained to medium-grained, and lenticular in geometry. Trough and planar cross-stratification are common sedimentary structures contained in these sandstones (EG&G 1991, 1995a). The depositional environment of the Arapahoe Formation has been interpreted as a subaerial fluvial system with associated channel, bar, and floodplain deposits (EG&G 1995a).

The sandstones are generally weathered to a depth of 30 to 40 ft below the base of the RFA. The weathered sandstone varies from pale orange to yellowish-gray and dark yellowish-orange in color. Unweathered sandstones are light to olive gray. Fractures have been noted in the weathered zone at depths of 5 to 14 ft. Arapahoe Formation sandstones comprise an important element of the groundwater flow regime at RFETS, and represent a relatively higher-velocity groundwater pathway in the UHSU (EG&G 1995b).

<u>Arapahoe Formation Claystones/Silty Claystones</u>

The Arapahoe Formation claystones and silty claystones are massive and blocky, and may contain thin laminae and stringers of sandstone, siltstone, and coal. The weathered claystones can extend to approximately 30 ft below the base of the RFA and, in some cases, farther. Weathered claystones range in color from pale yellowish-brown to light olive gray and are moderately stained with iron oxides. Unweathered claystones are typically dark gray to yellowish-gray.

Fractures have been encountered between 6 and 26 ft in depth in Arapahoe Formation claystones and are associated with ironstone concretions and calcareous deposits in the weathered zone. Small vertical, horizontal, and 45-degree fractures have been encountered in the unweathered zone at depths of 30 ft to over 100 ft. Many of the shallower fractures are stained with iron oxide or calcareous deposits, suggesting groundwater movement (Rockwell 1988). Additional information regarding fracturing within the Arapahoe Formation is provided in the White Paper entitled Analysis of Vertical Contaminant Migration Potential (RMRS 1996).

2.4.3.2 Laramie Formation

The upper contact of the Laramie Formation generally occurs at a depth of approximately 100 ft below the RFETS ground surface; however, in the IA OU and the east BZ OU, where the RFA is thinner and the Arapahoe Formation is thin or absent, the depth to the Laramie Formation is much less. The Laramie Formation is informally divided into two intervals: (1) an upper claystone unit, and (2) a lower unit composed of sandstone, siltstone, and claystone with coal layers (Weimer 1973). The upper unit is approximately 300 to 500 ft thick and consists primarily of olive-gray and yellowish-orange kaolinitic claystones, with lesser amounts of dark-gray to black carbonaceous claystones, discontinuous coal beds, and lenticular sandstone deposits (EG&G 1995a). These sandstone beds are less mature than those of the Arapahoe Formation, being finer-grained and including more silt, clay, and carbonaceous material. Because they are discontinuous and contained within relatively tight, low-permeability claystones, these sandstone lenses do not appear to represent a viable pathway for groundwater, and the upper Laramie Formation is considered a confining unit (EG&G 1995b). The lower unit of the Laramie Formation is approximately 300 ft thick and consists of kaolinitic claystones, sandstones, and coal beds (EG&G 1995a).

2.4.3.3 Fox Hills Sandstone

The Fox Hills Sandstone is 90 to 140 ft thick at RFETS and consists of well-sorted, quartz-rich sandstones (EG&G 1995a).

2.4.4 Structure

The site is located on the western flank of the Denver Basin, with the RFETS western boundary located approximately 2 miles east of steeply dipping strata on the eastern flank of the Front Range uplift. The Denver Basin is a north-south-trending, asymmetrical basin with a steep western flank and shallow eastern flank. The basin is more than 13,000 ft deep at its deepest point and contains bedrock of Paleozoic, Mesozoic, and Cenozoic age (Figure 2.12).

Earlier studies at RFETS (EG&G 1995b) suggested outcrops of the upturned beds on the western side of the site act as a primary source of recharge to the UHSU groundwater at the site. Modeling results and the Site-Wide Water Balance (SWWB) study indicate direct recharge within the IA may be more important than previously estimated (K-H 2002a). Direct recharge from infiltration is more than an order of magnitude greater than the groundwater flux from the western part of the site. The majority of groundwater from the western part of the site diverges to drainages on the north and south, and therefore does not reach the IA OU (K-H 2002a; DOE 2005).

2.4.5 Seismic Conditions

The site is located approximately 2 miles east of the steeply dipping strata along the western flank of the Denver Basin. The Denver Basin, a north-south-trending, asymmetrical basin containing Paleozoic, Mesozoic, and Cenozoic strata, occurs on the east flank of the Front Range uplift. Steeply dipping Pennsylvanian to Cretaceous bedrock formations underlying RFETS are exposed at the surface and by the Quaternary RFA and Verdos alluvium, colluvium, and other unconsolidated sedimentary deposits of Recent age.

The local structure beneath RFETS has been assessed in numerous studies that are summarized in the Geologic Characterization Report (EG&G 1995a). Several faults have been identified in the vicinity of RFETS using seismic and stratigraphic techniques (Figure 2.13). These faults have been interpreted to be of Laramide and younger age and tectonic or syndepositional in origin. Based on seismic, drilling, and trenching data, these faults are thought to have been inactive for at least 1 million years. None of these faults appear to extend into or offset the overlying RFA or other recent deposits.

Evaluation of geologic and topographic features does not indicate recent movement has occurred along these faults. Consequently, based on current available information, the site is in a zone of relatively low seismic activity. A seismic hazard study performed at the site in 1994 concluded there was a low probability of seismic activity at the site (REI 1994). This is confirmed based on U.S. Geological Survey (USGS) general maps of peak horizontal bedrock acceleration. RFETS is located in an area with a 2-percent chance of exceeding, in 50 years, a peak bedrock acceleration equivalent to 0.12 the acceleration due to gravity (g) (USGS 2002). Current information also indicates that both the known and inferred faults are confined to the bedrock formations and do not influence groundwater flow or contaminant transport in the UHSU at the site (K-H 2002a).

2.4.6 Geomorphology

The dominant geomorphic processes at RFETS currently include side-slope erosion and the erosional activity of Walnut and Woman Creeks. The drainages erode and convey sediment, and are the primary forces that develop the slopes in the valleys. Slope erosion occurs as a result of precipitation while some movement of slope soils results from mass wasting, as occurs with landslides and slumps. Stream erosion occurs primarily by channel incision and headward erosion (active elongation of stream profiles by eroding the upstream end) as channels advance upstream.

North and South Walnut Creeks are at an immature stage of development. These drainages have fairly steep, V-shaped cross sections, and narrow floodplains characteristic of relatively immature geomorphologic development. Streams at this stage of development move relatively large quantities of sediment, particularly during heavy precipitation events, by eroding their channels through stream downcutting. In addition to downcutting their channels, the stream channels exhibit headward erosion. Alternately, Woman Creek has a more U-shaped cross section meanders and a broader floodplain compared to North and South Walnut Creeks, thereby suggesting a more mature stage of development. Less channel erosion likely occurs in the Woman Creek drainage.

Slumps and slides (including rotational failures) have developed on the hillslopes of Woman and Walnut Creeks in areas where shallow groundwater has saturated the unconsolidated material and weathered bedrock. The saturated condition can cause an increase in soil pore pressure and reduces the soil shear strength until the slope fails. Slumps also occur in locations where the stream flow has undercut the base or toe of the slope.

Geomorphic processes such as those that result from erosion of embankments and collection of sediments in the ponds are expected to be very slow. Areas of the site have been graded and revegetated as necessary to account for removal of manmade features (although some manmade features remain), and taking erosion processes into consideration. The effects of geomorphic processes are expected to be minimal between the periodic site evaluations that may be required in the future.

The Original Landfill cover is an engineered soil cover with surface drainage controls and a toe buttress that greatly enhances the stability of the Original Landfill. Due to these enhancements, the geomorphic processes described in this section will be minimized at the Original Landfill compared to adjacent areas.

The Present Landfill cover is an engineering cover system with surface drainage controls and erosion protection. The design of the cover system addressed the stability of the cover slopes meeting engineering standards of practice. Due to the design of the cover system, the geomorphic processes described in this section will be minimized at the Present Landfill compared to adjacent areas.

2.4.7 Soils

RFETS soils form a pattern related to geologic parent materials, geomorphic landforms, relief, natural vegetation, and climate processes. The U.S. Department of Agriculture (USDA) Soil Conservation Service (SCS) developed map-unit models based on aerial photographs to reasonably predict the types of soils in an area. The boundaries of the map units were refined and the map-unit models were tested by digging test pits and recording the characteristics of the soil profiles studied (EG&G 1995c).

Soils are taxonomically classified based on specific soil properties (for example, number and size of clasts, particle-size distribution, acidity, distribution of plant roots, and structure of soil aggregates) and the arrangement of horizons within the soil profile. Figure 2.14 illustrates the SCS map units for RFETS defined at the soil-series level. There are four general SCS soil types at RFETS, associated with the geologic map units, as follows:

- Pediment (flat upland area, predominantly Flatirons soil series) soils are located on the broad, dissected, eastward-sloping pediment surface in the western portion of the site. These soils are associated with the RFA geologic map unit.

- Valley-slope soils (for example, Nederland and Denver-Kutch-Midway soils) are located in the stream-cut valleys of the intermittent Rock Creek, Walnut Creek, and Woman Creek drainages. These soils are associated with the Laramie Formation, Arapahoe Formation, and landslide geologic map units.

- Hilltop soils of the eastern third of RFETS (including the Flatirons soil series) are similar to valley-slope soils and are associated with the Laramie and Arapahoe Formations. Localized areas on hill summits are associated with Terrace Alluvium.

- Drainage-bottom soils (for example, Haverson soils) are forming in recent alluvium along drainage bottoms.

A comparison between the geologic map (Figure 2.11) and the soils map (Figure 2.14) illustrates the relationship between soils at the soil-series level and geologic map units. Specific geotechnical properties of the various soil types located within and around RFETS are described in Table 2.1.

2.5 Surface Water Hydrology

The majority of the RFETS drainage area lies in the upper reaches of the 86-square-mile Big Dry Creek basin. Big Dry Creek joins the South Platte River approximately 40 miles northeast of RFETS, near Brighton, Colorado. The smaller portion of RFETS not in the Big Dry Creek basin lies in the Rock Creek watershed, which is part of the Boulder Creek basin. To the west, RFETS is hydrologically separated from the foothills by Coal Creek, located approximately 1 mile west of the site's western boundary.

Streams and seeps at RFETS are largely ephemeral or intermittent.[3] Stream reaches gain flow (from groundwater discharging to the surface) or lose flow (from surface water recharges to groundwater, plant evapotranspiration [ET], and other factors), depending on the season and precipitation amounts.

Surface water flow across RFETS is primarily from west to east, with four drainages traversing the site (Figure 2.1):

- Rock Creek – Major drainage in the northwestern part of RFETS (does not receive runoff from the IA OU);
- Walnut Creek – Major drainage in the north-central portion of RFETS, including the majority of the IA OU;
- Woman Creek – Major drainage on the southern side of RFETS, including the southern portion of the IA OU; and
- South Woman Creek – Minor drainage, including Smart Ditch, in the far southern section of RFETS (does not receive runoff from the IA OU).

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[3] The U.S. Army Corps of Engineers (USACE) defines ephemeral and intermittent streams in the following manner:

- Ephemeral stream - A stream that has flowing water only during, and for a short duration after, precipitation events in a typical year. Ephemeral stream beds are located above the water table year-round. Groundwater is not a source of water for the stream. Runoff from rainfall is the primary source of water for stream flow in an ephemeral stream.
- Intermittent stream - A stream that has flowing water during certain times of the year, when groundwater provides water for stream flow. During dry periods, intermittent streams may not have flowing water. Runoff from rainfall is a supplemental source of water for stream flow in an intermittent stream.

Even the largest drainages at RFETS typically have defined channels that are relatively narrow, ranging in bottom widths from 2 to 10 ft. The channel bottoms intermittently vary between vegetation and exposed sediments and cobbles. Vegetation near the intermittent streams is dominated by riparian woodland/shrubland community types, with wet meadow and marsh species near seeps and ponds (see Section 2.9.1 for further discussion on vegetation).

A detailed discussion of each of the drainages is provided in Sections 2.5.1 through 2.5.4. Information is included on water routing, water volumes, peak flow rates, retention ponds, other structures, and a general description of the watershed. As part of water routing, under nonemergency conditions, the terminal ponds (Ponds A-4, B-5, and C-2) are sampled prior to their discharge. As discussed above, four drainages exist at RFETS and are discussed in order from north to south.

2.5.1 Rock Creek

The Rock Creek drainage covers the northwestern portion of the BZ OU (Figure 2.1). The Rock Creek watershed does not receive runoff from the IA OU. The watershed area is approximately 1,499 acres (as measured by gaging station GS04 [Figure 2.1]), and includes an area west of the RFETS boundary. Rock Creek is classified as stream segment 8 in the Boulder Creek basin by the Colorado Water Quality Control Commission (CWQCC).

The Rock Creek drainage basin consists of an alluvial terrace that slopes gently to the northeast and is dissected by Rock Creek and its tributaries, which flow generally from southwest to northeast. The principal surface features in the Rock Creek drainage include (from north to south) Short Ear Branch, Plum Branch, Mahonia Branch, Snowberry Branch, and Lobelia Branch (Figure 2.1). Two ponds are visible along the main stem of Rock Creek. The westernmost of the two ponds, located at the southern end of the Rock Creek drainage, is designated Lindsay 2. The other is Lindsay 1. The ponds predate federal ownership of the site. Flow in Rock Creek is ephemeral; however, portions of Rock Creek are perennial. The hydrology of the Rock Creek drainage is not expected to change as a result of the accelerated actions.

The mean annual discharge volume in Rock Creek, measured at gaging station GS04, is approximately 235 acre-feet (ac-ft) per year (based on flow records from October 1, 1996, through July 31, 2005). The peak flow rate measured at GS04 during the same period is 35.4 cfs. These flow data are summarized, along with flow data for other RFETS locations, in Table 2.2.

2.5.2 Walnut Creek

The Walnut Creek drainage comprises the central third of RFETS, and receives runoff from the majority of the IA OU, as well as the northeast BZ. The area of the Walnut Creek watershed upstream from gaging station GS03 is approximately 1,878 acres. The Walnut Creek basin includes several current or former tributaries within the RFETS boundaries, including (from north to south) McKay Ditch (formerly a tributary of Walnut

Creek), No Name Gulch, North Walnut Creek, and South Walnut Creek. Descriptions of these subbasins, and the off-site flow of Walnut Creek, are provided in this section.

2.5.2.1 McKay Ditch

The McKay Ditch runs west to east across the northern BZ OU, and is hydrologically isolated from the IA OU. The ditch was formerly a tributary to Walnut Creek within the RFETS boundaries. However, in 1999, an underground pipeline was constructed in the northeast BZ OU to reroute McKay Ditch water and prevent it from commingling with water in Walnut Creek discharged from Pond A-4 or B-5. This configuration allows the City of Broomfield to divert water from Coal Creek or the South Boulder Diversion Canal (both west of RFETS). The diverted water flows into the open-channel McKay Ditch and McKay Bypass Canal, across the northern RFETS BZ OU, and into the underground pipeline that runs eastward for approximately 3,500 ft on site before being routed underneath Indiana Street. On the eastern side of Indiana Street, the pipeline daylights and the water flows directly to Great Western Reservoir, where the water is stored by the City of Broomfield for irrigation purposes. The McKay Ditch is classified as stream segment 4a in the Big Dry Creek basin by the CWQCC (Figure 2.1).

The McKay Ditch and Bypass Canal have a combined length of approximately 3.5 miles on RFETS property. The channel lining alternates between grass and exposed cobbles, and has grade-control structures constructed from rock and spaced intermittently. Water is diverted out of the McKay Ditch by a concrete diversion wall into a catch basin, and then into the diversion pipeline. The pipeline is approximately 3,500 ft long, ranges in diameter from 42 to 48 inches (high-density polyethylene pipe), and has a capacity of 110 cfs. Flows in excess of 110 cfs run over the diversion wall and into the McKay Ditch drainage downstream. To support downstream wildlife habitat, a 1-inch-diameter opening exists in the diversion wall near its base. The small opening is designed to provide a stream of water, when water is flowing in the McKay Ditch, to supply the habitat in the McKay Ditch drainage downstream of the diversion structure.

The McKay Ditch is generally dry. Flows in the ditch historically occur in the spring, when the City of Broomfield water rights are exercised and water is diverted into the ditch, or when overland runoff is captured and transported by the ditch. Future flows in the McKay Ditch are expected to be similar to past flows given that site activities do not impact the configuration of the ditch, and operations are managed by the City of Broomfield.

The mean annual discharge volume in the McKay Ditch, measured at gaging station GS35 (downstream from the diversion to the pipeline), is approximately 69 ac-ft per year. The discharge volume for the ditch is based on flow records collected from October 1, 1997, through July 31, 2005. The peak flow rate measured during the same period is 23.6 cfs. These flow data are summarized, along with flow data for other RFETS locations, in Table 2.2.

2.5.2.2 No Name Gulch

No Name Gulch is located in the north BZ OU. The headwaters of the drainage contain the Present Landfill and East Landfill Pond. The East Landfill Pond receives runoff from the Present Landfill area and the watershed immediately surrounding the pond, and is hydrologically isolated from the IA OU. A summary of the East Landfill Pond dam and pond characteristics and the pond operating protocol is provided in Table 2.3.

No Name Gulch flow is intermittent, with periodic runoff occurring most frequently in the spring. The closure of the former Present Landfill, with a RCRA-compliant cover constructed over the landfill area, is expected to generate additional runoff compared to the historic runoff pattern. Drainage ditches along the perimeter of the Present Landfill cover allow free drainage of the geosynthetic composite cover and drainage layer, and direct surface water away from the landfill and into No Name Gulch east of the East Landfill Pond Dam. The perimeter channels are vegetated earthen channels; steeper-sloped sections are riprapped. The discharges of these perimeter channels are in the same location as the historical perimeter channels (east of the East Landfill Dam and north and south of the East Landfill Pond) (DOE 2004c). Small amounts of additional water will flow from the perimeter channels due to the impermeable cover of the landfill.

The mean annual discharge volume in No Name Gulch, measured at gaging station GS33, is approximately 17 ac-ft per year (based on flow records from October 1, 1997, to July 31, 2005). The peak flow rate measured during the same period is 6.8 cfs. These flow data are summarized, along with flow data for other RFETS locations, in Table 2.2.

As discussed previously, No Name Gulch will receive increased runoff compared to that observed historically as a result of additional flow routed through the drainage ditches along the perimeter of the Present Landfill (DOE 2004c).

2.5.2.3 North Walnut Creek

Runoff from the northern portion of the IA OU flows into North Walnut Creek, which has four retention ponds (Ponds A-1, A-2, A-3, and A-4). A summary description of the dams, flow routing, and pond operating protocol in North Walnut Creek is provided in Table 2.3. North Walnut Creek upstream from Pond A-4 is classified as stream segment 5 in the Big Dry Creek basin by the CWQCC; downstream from Pond A-4, North Walnut Creek is classified as stream segment 4b. Pond A-4 water is sampled prior to discharge into North Walnut Creek.

In contrast to the majority of other site drainages, North Walnut Creek has historically had continuous flow (as measured at gaging station SW093, located immediately northeast and downstream from the IA OU), except during extended dry periods. The hydrology of the North Walnut Creek drainage following accelerated remedial actions is expected to differ from the hydrology when the IA existed. Removal of buildings and pavement from the IA significantly reduces the volumes and peak discharge rates of runoff.

When buildings and pavement existed in the IA, the mean annual discharge volume from North Walnut Creek, measured at gaging station SW093 (upstream from Pond A-1), was approximately 145 ac-ft per year (based on flow records from October 1, 1996, through July 31, 2005). The peak flow rate measured during the same period was approximately 135 cfs (Table 2.2).

To predict surface water discharge volumes for the site configuration after accelerated actions are complete, the MIKE SHE model was used. It simulates multiple integrated hydrologic processes, including surface water and groundwater interaction. A description of the MIKE SHE model, including model uncertainties, is provided in the SWWB Modeling Report for RFETS (K-H 2002a). Although the SWWB model provides the best estimate of time-varying flows throughout the site, results are best utilized in assessing the relative changes in hydrologic response due to site modifications, or climate variations. As a result, emphasis was placed on the change in hydrologic responses such as surface flows (K-H 2005a).

With accelerated actions complete, hydrologic model simulations show that flows in North Walnut Creek will significantly decrease compared with pre-closure hydrologic conditions where imported water, pavement, and subsurface drains contributed to the overall water balance at the site. The annual discharge volume predicted at station SW093 after completion of accelerated actions, assuming a typical annual climate sequence (Water Year 2000), is approximately 51 ac-ft per year. A range of model-predicted annual discharge volumes for station SW093, for varying climatic conditions, is presented in Table 2.4.

Because there will be less inflow to the North Walnut Creek ponds than in the past (specifically Ponds A-3 and A-4, which have stream flows routed into them under routine conditions), the ponds are expected to fill more slowly and be discharged less frequently. Therefore, pond levels in the post-accelerated action condition are anticipated to change more slowly compared to pond levels during the pre-accelerated action condition. However, over the course of several years, the average pool depths in the ponds in the post-accelerated condition may not vary significantly compared to average pool depths in the pre-accelerated action condition. With respect to the North Walnut Creek interior ponds that are offline from routine flow routing (Ponds A-1 and A-2), the average pool level could reasonably be expected to be lower compared to the pre-accelerated action pond conditions.

2.5.2.4 South Walnut Creek

Runoff from the central portion of the IA OU flows into South Walnut Creek, which has five retention ponds (Ponds B-1, B-2, B-3, B-4, and B-5). A summary description of the dams, flow routing, and pond operating protocol in South Walnut Creek is provided in Table 2.3. South Walnut Creek upstream from Pond B-5 is classified as stream segment 5 in the Big Dry Creek basin by the CWQCC; downstream from Pond B-5, South Walnut Creek is classified as stream segment 4b (Figure 2.15). Pond B-5 water is sampled prior to discharge into South Walnut Creek.

Similar to North Walnut Creek, South Walnut Creek generally has historically had continuous flow (as measured at gaging station GS10, located immediately downstream from the IA OU), except during extended dry periods. The hydrology of the South Walnut Creek drainage following accelerated remedial actions is expected to differ from the hydrology when the IA existed. Removal of buildings, elimination of water historically imported for RFETS operations, elimination of the Sewage Treatment Plant discharge, and removal of pavement from the IA significantly reduce the volumes and peak discharge rates of runoff in this drainage (K-H 2002a).

When buildings and pavement existed in the IA, the mean annual discharge volume from South Walnut Creek, measured at gaging station GS10 (located above Pond B-1), was approximately 100 ac-ft per year (based on flow records from October 1, 1996, through July 31, 2005). The peak flow rate measured at GS10 during the same period was approximately 113 cfs (Table 2.2).

With accelerated actions complete, it is anticipated that flows in South Walnut Creek will be significantly diminished compared with the historic configuration of the site, when buildings and pavement generated additional runoff. The annual discharge volume predicted at station GS10 after accelerated actions are complete, based on model simulations for a typical climate year (Water Year 2000), is approximately 12 ac-ft per year. A range of model-predicted annual discharge volumes for station GS10, for varying climatic conditions, is presented in Table 2.4.

Because there will be less inflow to the South Walnut Creek ponds than in the past (specifically Pond B-5, which has stream flows routed into it during routine conditions), Pond B-5 is expected to fill more slowly and be discharged less frequently. Therefore, the levels in Pond B-5 will change more slowly than during pre-accelerated action conditions. However, over the course of several years, the average pool depth in Pond B-5 in the post-accelerated condition may not vary significantly compared to the average pool depth in the pre-accelerated action condition.

With respect to the interior B-Series Ponds that are offline from routine flow routing (B-1, B-2, and B-3), the average pool levels could reasonably be expected to be lower compared to the pre-accelerated action pond conditions. Pond B-4 is operated as a flow-through pond and is not expected to vary considerably compared with its pre-accelerated action condition.

2.5.2.5 Walnut Creek

Downstream from terminal Ponds A-4 and B-5, North and South Walnut Creeks merge to form Walnut Creek. This reach of Walnut Creek is classified as stream segment 4b in the Big Dry Creek basin by the CWQCC (Figure 2.15). Water in the lower reach of Walnut Creek flows through the “Flume Pond,” a small (less than 1 acre-foot), unmanaged pond located approximately 300 ft west of the RFETS boundary at Indiana Street.

When buildings and pavement existed in the IA, the mean annual discharge volume measured at gaging station GS03 (at Walnut Creek and Indiana Street) was approximately 434 ac-ft per year (based on flow records from October 1, 1996, through July 31, 2005). The peak flow rate measured during the same period was approximately 57 cfs (Table 2.2).

With accelerated actions complete, it is anticipated that flows in Walnut Creek will be significantly diminished compared with the historic configuration of the site, when buildings and pavement generated additional runoff. The annual discharge volume predicted at station GS03 after accelerated actions are complete, based on model simulations for a typical climate year (Water Year 2000), is approximately 56 ac-ft per year. A range of model-predicted annual discharge volumes for station GS03, for varying climatic conditions, is presented in Table 2.4.

In addition to the Walnut Creek tributaries discussed in earlier sections, several other small drainage swales exist on the western side of Indiana Street, within the RFETS boundary. These drainages are tributary to Walnut Creek, but merge with Walnut Creek downstream from the site boundary (Figure 2.1). Therefore, the runoff from these small drainages is not measured by station GS03. These vegetated sub-basins were not altered by accelerated remedial actions. Although these catchments generate little runoff, they are noted here to complete the description of the Walnut Creek watershed.

2.5.2.6 Walnut Creek Flow Off Site

Downstream from the site, east of Indiana Street, Walnut Creek flows into a splitter box operated by the City of Broomfield. The splitter box is normally configured to divert Walnut Creek flows into the Broomfield Diversion Ditch and around the south side of Great Western Reservoir, thereby preventing RFETS runoff in Walnut Creek from entering the reservoir (Figure 2.1). East of the reservoir, the Broomfield Diversion Ditch angles northward and rejoins Walnut Creek.

Great Western Reservoir was formerly used to store the drinking water supply for the City of Broomfield. However, during the 1990s, the Great Western Reservoir Replacement Project was implemented as part of the “Option B” project, funded by DOE to protect downstream water supplies from potential RFETS contamination.[4] The Great Western Reservoir Replacement Project involved the purchase of water rights, construction of a pipeline from Carter Lake (located near Loveland, Colorado) to Broomfield, construction of a drinking water treatment plant, and development of associated infrastructure. Great Western Reservoir was then taken offline as a drinking water supply reservoir, in accordance with terms of the grant that funded the project, although it is still used by the City of Broomfield as a storage facility for irrigation water.

East of Great Western Reservoir, Walnut Creek flows into Big Dry Creek. The 86-square-mile Big Dry Creek watershed is tributary to the South Platte River. The

[4] In the early 1990s, DOE, Westminster, Broomfield, and Congressman David Skaggs evaluated options for protecting downstream drinking water supplies from potential contamination from Rocky Flats. “Option B” was ultimately selected in 1991, and consisted of two major components: (1) the Great Western Reservoir Replacement Project, and (2) the Standley Lake Protection Project.

confluence of Big Dry Creek with the South Platte River is located north of Brighton, Colorado, approximately 30 miles northeast of RFETS.

2.5.3 Woman Creek

The Woman Creek drainage comprises the southern side of the site, and receives runoff from the southern portion of the IA OU as well as the majority of the southern BZ (Figure 2.1). The area of the Woman Creek watershed upstream from gaging station GS01 is approximately 1,602 acres. (It is noted that a Smart Ditch splitter box can be overtopped in a large storm, essentially adding an additional 792 acres to the Smart Ditch watershed, located south of the Woman Creek watershed [see Section 2.5.3.3]). Several tributaries to Woman Creek exist within the RFETS boundaries, and include, from north to south, the SID, Owl Branch, Antelope Springs Gulch, and South Woman Creek. Descriptions of these tributaries, the main channel of Woman Creek, and the off-site flow of Woman Creek are provided in this section.

2.5.3.1 SID

Runoff from the southern portion of the IA OU flows into the SID. The SID was constructed to intercept runoff from the southern portion of the IA so that it would flow into Pond C-2 instead of directly into Woman Creek. A summary of Pond C-2 dam and pond characteristics, and the operating protocol, is provided in Table 2.3. Pond C-2 water is sampled prior to discharge into Woman Creek. As a tributary to the main stem of Woman Creek, the SID is classified as stream segment 4a in the Big Dry Creek basin by the CWQCC.

The SID is a grass-lined, trapezoidal channel with ephemeral flow. Removal of impervious surfaces, such as buildings and pavement, from the IA OU reduces the discharge volumes and peak flow rates observed historically. In addition, the western 1,500 ft of the SID were eliminated when the cover was constructed for the Original Landfill.

When buildings and pavement existed in the IA, the mean annual discharge volume in the SID, as measured at gaging station SW027 (located at the downstream, or eastern end, of the SID), was approximately 22 ac-ft per year (based on flow records from October 1, 1996, through July 31, 2005). The peak flow rate measured during the same period was approximately 10 cfs (Table 2.2). However, as noted above, flows in the final configuration are anticipated to be significantly less than runoff from the historic configuration, when buildings and pavement generated additional runoff.

With accelerated actions complete, it is anticipated that flows in the SID will be significantly diminished compared with the historic configuration of the site, when buildings and pavement generated additional runoff. The annual discharge volume predicted at station SW027 after accelerated actions are complete, based on model simulations for a typical climate year (Water Year 2000), is approximately 2 ac-ft per year. A range of model-predicted annual discharge volumes for station SW027, for varying climatic conditions, is presented in Table 2.4.

2.5.3.2 Owl Branch

The Owl Branch of Woman Creek flows west on to the southwest quadrant of the RFETS property, and roughly parallels Woman Creek before joining it at a point approximately 1,800 ft east of the site's western boundary. Owl Branch is hydrologically isolated from the IA OU. Similar to the main stem of Woman Creek, Owl Branch is classified as stream segment 4a in the Big Dry Creek basin by the CWQCC (Figure 2.15).

Changes made to the site from accelerated actions are not expected to alter the watershed or hydrology in the Owl Branch of Woman Creek. The mean annual discharge volume measured in Owl Branch at gaging station GS06 (located on the RFETS western boundary where South Woman Creek enters the site) was approximately 21 ac-ft per year (based on flow records from October 1, 1996, through June 6, 2005). The peak flow rate measured during the same period was approximately 12 cfs (Table 2.2).

2.5.3.3 Antelope Springs Gulch

Antelope Springs Gulch conveys water from Antelope Springs, which normally flows throughout the year. Antelope Springs is located on the southern side of Woman Creek, in the southwest quadrant of the BZ OU. The seep is likely influenced by Rocky Flats Lake, located off site to the west. Antelope Springs Gulch flows northeast and joins Woman Creek approximately 2,500 ft upstream from Pond C-1. The Antelope Springs drainage is hydrologically isolated from the IA OU. As a tributary to the main stem of Woman Creek, Antelope Springs Gulch is classified as stream segment 4a in the Big Dry Creek basin by the CWQCC.

Changes made to the site from accelerated actions are not expected to alter the watershed or hydrology in Antelope Springs Gulch. The mean annual discharge volume of Antelope Springs Gulch, measured at gaging station GS16, was approximately 93 ac-ft per year (based on flow records from October 1, 1996, through July 31, 2005). The peak flow rate measured during the same period was approximately 9 cfs (Table 2.2).

2.5.3.4 South Woman Creek

South Woman Creek exists in the southern portion of the BZ OU. Along with two irrigation ditches, Smart Ditch and Smart Ditch 2, South Woman Creek is designated as stream segment 6 in the Big Dry Creek basin by the CWQCC (Figure 2.15). Both Smart Ditches are owned and operated by the Church Estate, not DOE or its contractors. Neither South Woman Creek, nor either of the Smart Ditches, receives runoff from the IA OU.

Water from Rocky Flats Lake, located west of the site, flows through Smart Ditch before it joins the headwaters of South Woman Creek. South Woman Creek continues flowing west until it reaches a splitter box, which can divert water into either of the following two drainages:

1. South Woman Creek flows west before joining Woman Creek approximately 1,000 ft west of the site boundary.

2. Smart Ditch flows southeast, through two ponds (D-1 and D-2, neither of which are operated by DOE), which are located in the southeastern corner of the BZ OU and are used for irrigation.

Smart Ditch 2 runs northeast of Rocky Flats Lake and is used to flood-irrigate a pasture west of RFETS. Both Smart Ditch and Smart Ditch 2 are typically dry, although each has an estimated flow capacity of 10 cfs. Because both ditches are far removed and hydrologically separated from the IA OU, limited flow or water quality data exist for these conveyances. Data for these ditches are not presented in this report.

2.5.3.5 Woman Creek

Woman Creek flows from west of the site on to the southwest quadrant of the RFETS property, and converges with the Owl Branch of Woman Creek at a point approximately 1,800 ft east of the site's western boundary. For its entire length at RFETS, Woman Creek is classified as stream segment 4a in the Big Dry Creek basin by the CWQCC (Figure 2.15).

The mean annual discharge volume measured at gaging station GS05 (located on the RFETS western boundary where Woman Creek enters the site) was approximately 108 ac-ft per year (based on flow records from October 1, 1996 through July 31, 2005). The peak flow rate measured during the same period was approximately 25 cfs (Table 2.2).

For approximately two-thirds of the length of the IA OU, Woman Creek is isolated from surface runoff from the IA OU because the SID intercepts surface flow and diverts it into Pond C-2. However, groundwater from portions of the southern IA OU discharges into Woman Creek. Woman Creek is designated as stream segment 4a in the Big Dry Creek basin by the CWQCC, similar to North Woman Creek and Owl Branch.

In the western reach of Woman Creek, the watershed that flows directly to Woman Creek was enlarged when the Original Landfill remediation eliminated the western 1,500 ft of the SID, thereby allowing runoff from the Original Landfill area to flow directly to Woman Creek. However, because the vegetated cover on the Original Landfill will not generate a substantial quantity of runoff, this change is expected to have a negligible effect on the total flow volume in Woman Creek.

Woman Creek flows through Pond C-1, which was reconfigured as a low-profile, flow-through structure in 2005. A summary of the Pond C-1 dam and pond characteristics, and the operating protocol, is provided in Table 2.3. Because Pond C-1 is operated as a flow-through pond, and its reconfigured pool level is similar to the historic pool level, and the Woman Creek flows are not affected substantially by the accelerated actions at the site, the levels in Pond C-1 are not expected to vary considerably compared with its pre-accelerated action condition.

Below Pond C-1 and upstream from Pond C-2, Woman Creek is diverted, via a concrete diversion wall and channel, around the northern side of Pond C-2. The channel diversion was constructed so that Pond C-2 would capture only runoff from the IA and be isolated from the flow in Woman Creek. Downstream from Pond C-2, the diversion channel rejoins the original Woman Creek channel prior to leaving the site.

Pond C-2 is discharged into Woman Creek. Historically, when buildings and pavement existed in the IA, a Pond C-2 discharge was typically necessary once per year. However, with the reduced runoff from the IA OU flowing into the SID, Pond C-2 discharges to Woman Creek are expected to be less frequent, based on normal climate conditions. Therefore, the levels in Pond C-2 will change more slowly than during pre-accelerated action conditions, although its average pool depth may not vary significantly, over an extended period of time, compared with the pre-accelerated action condition.

Because Pond C-2 discharges were historically a small percentage of the volume measured in Woman Creek, less frequent Pond C-2 discharges should not have a major impact on the overall hydrology of Woman Creek.

For the Woman Creek drainage, the mean annual discharge volume measured at gaging station GS01 (located on Woman Creek at Indiana Street) was approximately 272 ac-ft per year (based on flow records from October 1, 1996, through July 31, 2005). The peak flow rate measured during the same period was approximately 80 cfs (Table 2.2).

With the exception of the SID basin, changes made to the site resulting from accelerated remedial actions are not expected to have a major impact on the Woman Creek watershed or its hydrology. Based on model simulations of the site after accelerated actions have been completed, the annual discharge volume predicted at station GS01, for the Water Year 2000 climate, is approximately 130 ac-ft per year. For varying climatic conditions, a range of model-predicted annual discharge volumes for station GS01 is presented in Table 2.4.

As noted for North and South Walnut Creeks, because there will be less inflow to the Woman Creek basin ponds than in the past (in particular Pond C-2, which has stream flows routed into it during routine conditions), Pond C-2 is expected to fill more slowly and be discharged less frequently than in the past. Therefore, the levels in Pond C-2 will change more slowly than during pre-accelerated action conditions. However, over the course of several years, the average pool depth in Pond C-2 in the post-accelerated condition may not vary significantly compared to the average pool depth in the pre-accelerated action condition. Pond C-1 is operated as a flow-through pond and is not expected to vary considerably compared with its pre-accelerated action condition.

2.5.3.6 Woman Creek Flow Off Site

Woman Creek is part of the Big Dry Creek basin, similar to Walnut Creek. Downstream from the site, east of Indiana Street, Woman Creek flows into Woman Creek Reservoir. Woman Creek Reservoir was constructed in 1996 as a major component of the Option B water management project. The 400-ac-ft reservoir was constructed to capture Woman Creek surface water from RFETS before it flows into Standley Lake, which stores water for municipal drinking supplies and irrigation (CH2M Hill 1996).

The Woman Creek Reservoir is operated by the Woman Creek Reservoir Authority. Water stored in the reservoir is detained until analytical results indicate the water quality is acceptable for discharge. Water is normally pumped north, via an underground pipeline, to Walnut Creek at a point east of Great Western Reservoir. Occasionally, water from Woman Creek Reservoir is pumped to Mower Reservoir and used for irrigation. Mower Reservoir is located immediately north of Woman Creek Reservoir.

2.6 Hydrogeology

This section describes the hydrogeology of the site, including the unconfined and confined groundwater systems present. Unconfined groundwater flow occurs in unconsolidated geologic materials and in subcropping weathered bedrock claystones and sandstones comprising the UHSU. The UHSU consists of RFA, VFA, colluvium, underlying weathered bedrock claystones, and the Arapahoe No. 1 Sandstone.

Near-stream hydrology at RFETS is dominated by losses to ET, as demonstrated by site surface water flow monitoring and confirmed by an integrated hydrologic model of RFETS. The relatively small portion of infiltrating precipitation that does become shallow groundwater ultimately discharges to surface water before reaching the eastern site boundary. Therefore, the UHSU groundwater that has been impacted by site activities, both in the IA and BZ OUs, discharges to surface water prior to leaving RFETS.

In addition to the UHSU, a lower hydrostratigraphic unit (LHSU) has been identified at the site. The UHSU and LHSU are separated by extremely low-permeability claystone that serves to isolate them hydraulically (RMRS 1996). The LHSU is composed of the unweathered Arapahoe, Laramie, and Fox Hills Formations. The upper Laramie Formation claystones of the LHSU, with low permeability, act as an effective aquitard that restricts downward vertical groundwater flow from the UHSU to the LHSU. Background geochemical characterization of the UHSU and LHSU, based on major ion and stable isotope chemistry, shows that these units have statistically different groundwater chemistry, which provides further evidence of their hydraulic isolation from each other (EG&G 1993, 1995d). In addition, areas of the UHSU contain contaminant concentrations above drinking water standards, while the LHSU does not. Because the LHSU is hydraulically isolated from the UHSU, and because the LHSU does not show evidence of contamination from the UHSU, the LHSU is not a concern as a contaminant transport pathway from RFETS. (See Appendix A to the Groundwater IM/IRA for further discussion on the hydrogeologic relationship between the UHSU and LHSU [DOE 2005].)

The term "aquifer," as defined by 40 Code of Federal Regulations (CFR) Section 260.10, is a "geologic formation, group of formations, or a part of a formation that is capable of yielding a significant amount of water to a well or spring." An uppermost aquifer is also defined as "the geologic formation nearest the natural ground surface that is an aquifer, as well as lower aquifers that are hydraulically interconnected with this aquifer within the facility's boundary." The UHSU is considered equivalent to the uppermost aquifer at RFETS, although in many UHSU monitoring wells the amount of water available is insufficient to meet the definition of aquifer given above. While some UHSU monitoring wells are capable of producing enough groundwater for residential uses (K-H 2002b), groundwater at the site has never been used for drinking water, and this use is not anticipated in the future.

2.6.1 Regional Setting

The unconfined UHSU includes unconsolidated surficial materials, weathered portions of the Arapahoe and Laramie Formations, and all sandstones within the Arapahoe and Laramie Formations that are in hydraulic connection with overlying surficial deposits or the ground surface. Seeps are found along valley slopes at the contact of the surficial deposits and the underlying weathered bedrock. Water levels measured in UHSU versus bedrock wells at RFETS generally indicate a downward vertical hydraulic gradient. This suggests that water in the UHSU is perched on and bounded by claystone and silty claystone of the Arapahoe Formation (EG&G 1995b).

Beneath the surficial materials and consolidated deposits of the UHSU are the geologic units of the LHSU. The LHSU consists of the consolidated, unweathered bedrock of the Arapahoe and upper Laramie Formations that is not in hydraulic communication with the overlying UHSU. The Arapahoe and upper Laramie Formations comprising the geologic units of the LHSU consist of small quantities of sandstone and large quantities of claystones and siltstones. Because of the low permeability of the unweathered claystones, they restrict hydraulic communication with the UHSU (EG&G 1995b). LHSU wells that are screened in sandstones and bounded by relatively impermeable claystones and silty claystones exhibit confined conditions. In places where the uppermost LHSU sandstone is separated from UHSU materials by claystones and silty claystones, the sandstone may exist in a semiconfined condition (EG&G 1995b).

Sandstone beds of the lower Laramie Formation and the underlying Fox Hills Sandstone are grouped together as the regionally important Laramie/Fox Hills Aquifer. This aquifer is separated from the UHSU by the approximately 800- to 900-ft-thick LHSU confining layer (EG&G 1995b; DOE 2005). The LHSU acts as a confining layer to separate the UHSU from the Laramie/Fox Hills Aquifer, which constitutes a regional water supply resource.

2.6.2 Hydraulic Conductivities

Hydraulic conductivities within the UHSU are important with regard to contaminant transport at the site. Hydraulic conductivity values commonly used for calculations have been obtained from the geometric mean values presented in Table G-2 of the Hydrogeologic Characterization Report (EG&G 1995b), with updated geometric mean values for the RFA and VFA, including data from approximately 40 additional aquifer tests performed in 1995. Computed geometric mean hydraulic conductivity values for the materials that comprise the UHSU are as follows:

- RFA 4.18 x 10^{-4} centimeter per second (cm/sec)

(430 feet/year [ft/yr]);

- VFA — 9.20×10^{-4} cm/sec (950 ft/yr);
- Colluvium — 9.33×10^{-5} cm/sec (100 ft/yr);
- Arapahoe No. 1 Sandstone — 7.88×10^{-4} cm/sec (820 ft/yr); and
- Weathered claystone — 8.82×10^{-7} cm/sec (1 ft/yr).

Hydraulic conductivity values determined through calibration of the integrated flow model are similar but slightly different than these values (K-H 2002a). Modeling values generally are slightly higher (that is, within several factors) for the unconsolidated materials (RFA, VFA, and colluvium) and slightly lower for the bedrock (Arapahoe sandstone and claystone). This is reasonable given the variability (that is, orders of magnitude) of values within each soil type indicated.

Although geochemical and hydraulic data show the UHSU and LHSU are isolated from each other, limited hydraulic connection exists between these two units because of the downward vertical gradient between them. Hydraulic conductivities for the geologic materials in the LHSU range from approximately 2.5×10^{-7} to 2.8×10^{-10} cm/sec (approximately 3 to 0.003 inches/year) (RMRS 1996). This extremely low conductivity, coupled with the thickness of the LHSU, limits the vertical migration of contaminants from the UHSU to the regional water supply aquifers in the LHSU so that this is not a viable contaminant transport pathway (Hurr 1976; RMRS 1996).

2.6.3 Groundwater Occurrence and Distribution

RFETS is located near a regional groundwater recharge area (EG&G 1991), but is separated vertically from regional Denver basin aquifers by nearly 600 ft of lower-permeability material. UHSU groundwater recharge in the IA OU occurs from the infiltration of incident precipitation with a minor contribution as base flow from the upgradient area of the drainage basin that extends west to Coal Creek. Groundwater recharge in the BZ OU occurs from stream, ditch, and pond seepage. Groundwater recharge to the confined aquifers of the LHSU and the lower Laramie Formation and Fox Hills Sandstone occurs as precipitation infiltrates the steeply dipping western edge of the Denver Basin, west of RFETS.

In the western part of RFETS, where the thickness of the RFA may exceed 100 ft, the depth to UHSU groundwater is 50 to 70 ft below ground. The depth to water generally becomes shallower, and the saturated thickness thinner, from west to east as the alluvial material thins and the underlying claystones are closer to the ground surface.

2.6.3.1 Groundwater Flow

At RFETS, unconfined groundwater flows vertically and horizontally within the UHSU materials and horizontally along the contact of the UHSU with the unweathered bedrock. The general flow direction is from west to east, with the tendency to flow away from the mesa tops into the drainages. UHSU groundwater flow is largely controlled by the topography of the bedrock surface and the hillslopes. UHSU groundwater that has been impacted by site activities discharges to surface water prior to leaving RFETS.

The potentiometric surface of groundwater in the UHSU has been mapped for the second and fourth quarters of 2003,[5] and is shown on Figure 2.16 and Figure 2.17, respectively.[6] The periods illustrated, spring and fall, represent the times of year when static water levels are expected to be highest and lowest, respectively. The potentiometric surface maps confirm the propensity of the UHSU groundwater to flow toward the drainages and discharge to surface water.

The generalized UHSU groundwater flow for the reconfigured RFETS was determined through the use of the SWWB model (K-H 2002a, 2004b). The simulated modeling results indicate closure-condition groundwater flow velocities change little from the configuration of RFETS prior to closure. This is because hillslope morphology (surface and bedrock topography) strongly controls groundwater flow directions at RFETS. Model estimates of groundwater flow directions are shown on Figure 2.18 as arrows. The length of each arrow does not correspond to a flow velocity.

Groundwater discharges from the UHSU to streams as base flow, or in nonstream areas as seeps, or springs. Within the site area, only the Antelope Springs area south of Woman Creek discharges groundwater continuously (that is, springflow by definition) to surface water (GS16 gage). Baseflow contributions to streamflow were modeled using the integrated SWWB model (K-H 2002a). Results of equilibrated closure configuration conditions indicate that ephemeral baseflow will occur along several of the FCs (FC-1, FC-2, and FC-4). The model results also suggest that the central IA just south of the former B707/Central Avenue will likely produce seepflow that will flow into the South Walnut Creek drainage for wetter periods (K-H 2005a).

Other groundwater discharges to the ground surface at RFETS occur as seeps (defined by limited and ephemeral discharge). Seepflow is typically generated at the head of stream drainages and along upper valley sides, where lower-permeability bedrock emerges at the groundwater surface and forces groundwater to discharge to the surface. Notable seep areas are easily identified by the presence of phreatophytes (plant species with roots that extend to the water table). Seeps are common on north-facing slopes where ET impacts on groundwater discharges are less than other slopes. The seeps generally provide insufficient water to become sources of overland flow; flow rates have been estimated. Most seep locations denoted in the 1995 Hydrogeologic Characterization Report (EG&G 1995b), based on prior mapping, aerial photography, and field reconnaissance

[5] The second and fourth quarter 2003 data were selected to represent the potentiometric surface because it was the final IMP year, with the full groundwater level coverage (approximately 300 wells). Subsequent years had reduced coverage resulting in a lower potentiometric surface. Integrated hydrologic modeling after surface recontouring and revegetation within the IA OU indicate that the general groundwater flow directions do not change because of the dominance of the hillslope topography on flow directions (K-H 2005a).

[6] The seep areas identified on these figures are from the 1995 Hydrogeologic Characterization Report (EG&G 1995b). In addition, for Figures 2.16 and 2.17, some data points may lack result values printed on these figures due to the close proximity of the locations and software limitations.

(displayed on Figure 2.19), remain inactive during typical climate years, and only become active during wetter climate periods.

The bedrock surface has been modified in some areas of the IA OU due to incised utility corridors and excavations for building basements and other structures. These modifications locally affect the occurrence, distribution, and flowpath of groundwater. The potentiometric surfaces shown on Figure 2.16 and Figure 2.17, and published in previous reports, reflect these modifications. The removal of impermeable surfaces (parking lots, roads, and so forth) has resulted in an increase in the infiltration in many areas. Accelerated actions or land configuration activities have also added backfill where buildings were previously located, disrupted subsurface flowpaths, and removed the water supply system. This was previously a source of groundwater recharge due to leakage from the water supply system's subsurface distribution piping. The cumulative impact of these changes on groundwater occurrence and distribution will be evaluated through the integrated monitoring program that will be implemented after the accelerated actions are complete. It is unlikely that the cumulative impacts will be realized prior to the implementation of the final remedy pursuant to the Corrective Action Decision/Record of Decision (CAD/ROD). It may take many years before changes result in a new "steady-state" groundwater level and flow condition. The evaluation of groundwater occurrence and distribution data will be included in future periodic reviews, as appropriate.

2.7 Meteorology

RFETS has a semiarid climate typical of much of the central Rocky Mountain region, characterized by dry, cool winters and warm summers. The topography of the area greatly influences the climate, with higher-elevation areas of the Front Range immediately to the west and gently rolling plains to the east.

2.7.1 Precipitation

Average annual precipitation at the site is approximately 14.3 inches (36.3 centimeters [cm]), based on 43 years of precipitation records.[7] Rainfall is highest from April through June, with approximately 41 percent of the average annual precipitation, as either rain or snow, occurring during those months. Fall and winter are typically drier seasons. Monthly precipitation data are summarized in Table 2.5.

Analysis of precipitation data collected at RFETS from 1993 through 2004 indicates that approximately 25 percent of the days had precipitation measured above 0.01 inch (0.025 cm). Only slightly more than 1 percent of the days had precipitation measured at greater than 0.5 inch (1.3 cm).

Intense rainstorms along the Front Range are frequently of relatively short duration. Analysis of a 73-year record of rainfall at the Denver rain gage revealed that of the 73

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[7] Forty-three years of precipitation record include data from 1964 through 1977 (AeroVironment 1995), 1984 through 1993 (AeroVironment 1995), and 1994 through 2004 (K-H precipitation data).

most intense storms analyzed, 68 had the most intense period begin and end within the first hour of the storm. Furthermore, 52 of the storms had the most intense period begin and end within the first half-hour of the storm (UDFCD 2001). This pattern of highest intensity early in a rainstorm is common for storm events observed at RFETS.

2.7.2 Temperature

Temperatures at RFETS are relatively moderate; extremely warm and cold weather is usually of short duration. Average daily temperatures in July range from 58^{o} Fahrenheit (F) to 85^{o}F (14^{o} Celsius [C] to 29^{o}C), while average daily temperatures in January range from 20^{o}F to 47^{o}F (-9^{o}C to 8^{o}C) (AeroVironment 1995). The growing season, from the last spring freeze to the first autumn freeze, is approximately 148 days per year (RMRS/DOE 1995). Monthly temperature data, collected between 1964 and 2004, are summarized in Table 2.6.

2.7.3 Winds

Winds at RFETS, although variable, are predominately from the northwest quadrant. Wind speeds at 10 meters (m) above ground level average between 9 and 10 miles per hour (mph) (4 to 4.5 meters per second [m/s]). Strong winds occur predominantly out of the west-northwest, and during the winter and spring months. RFETS occasionally experiences gusts in excess of 100 mph (45 m/s). Strong winds are generally associated either with frontal passages or “Chinook” episodes, caused by the acceleration of westerly winds due to pressure differences over the Front Range, resulting in warm, dry, gusty conditions. Monthly wind speed data, collected between 1964 and 2004, are summarized in Table 2.7.

During periods when RFETS is not under the influence of strong storm systems or other synoptic patterns, the topographic differences between the western and eastern portions of the site produce a daily cycle of thermally driven upslope/downslope flow. Light winds flow upslope during the day as the warming land surface heats the adjacent air, with downslope winds occurring as the land surface cools after sunset. The distribution of wind speed and direction, based on 2004 data, is shown on Figure 2.20.

Stability reflects the tendency for vertical motion in the atmosphere and can be an important factor in determining air pollutant concentrations, as more stable conditions inhibit vertical dilution of pollutants emitted near ground level. Unstable conditions occur at RFETS approximately 11 percent of the time (RMRS/DOE 1995). Stable conditions occur approximately 43 percent of the time, while neutral conditions occur with the highest frequency, 46 percent of the time (RMRS/DOE 1995).

A temperature inversion, where warmer air overlies cooler air at the surface, often acts as a “lid” to hold pollution near the ground. Temperature inversions are common at RFETS and develop on most cloudless nights, even in the summer. During winter, such inversions can persist all day. Inversions can also occur when there are high winds aloft.

2.8 Human Populations and Land Use

As discussed in Section 2.2, RFETS is located at the interface of the Great Plains and Rocky Mountains. Higher-elevation areas west of RFETS are characterized by rugged terrain and relatively sparse human population. In contrast, the plains east of RFETS are characterized by relatively gentle topography and higher population density associated with the greater Denver metropolitan area. RFETS is located in an area of growing population with residential and commercial development of lands historically used for farming and grazing, primarily to the north, east, and south. This development is somewhat countered by local government acquisition and preservation of open space, including land adjacent to RFETS, primarily directly to the west and north.

2.8.1 Population and Housing

As of 2004, approximately 2.6 million people were living in the Denver metropolitan area counties. Between 1990 and 2000, the population of the Denver metropolitan area increased by approximately 556,000 people (29.9 percent), according to the Denver Regional Council of Governments (DRCOG) (DRCOG 2004).

Table 2.8 presents the population and number of households in Denver-area counties in 2000, along with the estimated population and household numbers for 2004. The distribution of households and population within a radius of 20 kilometers (12.4 miles) of the site in 2004 is shown on Figure 2.21. Continued growth is expected for these areas. DRCOG projects the population in the Denver metropolitan area will increase by more than 1 million additional people from 2000 to 2025, or approximately 42 percent (DRCOG 2004).

In addition to the trend of increasing population in adjacent counties, residential population has moved closer to the site since 1990. The communities of Superior (north of RFETS), Broomfield (northeast of RFETS), and Westminster and Arvada (east and southeast of RFETS) have experienced rapid growth in recent years. As a result, residential housing, as well as increased commercial and industrial uses, has developed primarily to the north, northeast, east, and southeast of RFETS, in areas that were vacant land when the 1990 census was conducted. Some of these developments are described in more detail in Section 2.8.2.

2.8.2 Surrounding Land Use

Until recently, land around the site consisted primarily of rangeland, preserved open space, mining areas, and low-density residential areas. However, this rural pattern is beginning to change due to the spread of development from the surrounding communities. The towns of Superior and Broomfield have already experienced extensive development north and northeast of the site. Superior has seen substantial residential growth, and a commercial center has been developed at the intersection of McCaslin Boulevard and U.S. Highway 36 (Figure 2.1).

Northeast of the site, an extensive area of commercial, residential, and office space (Interlocken and the Flatirons Crossing area) has developed over the past 5 to 7 years between State Highway 128 and U.S. Highway 36. During this same period, several office complexes, a county jail, and multifamily residential housing unit have been constructed south of State Highway 128 and east of Indiana Street. In addition, the Jefferson County Airport, located approximately 3 miles east of RFETS, is surrounded by recent business park and light industrial developments.

State-owned lands southwest and west of the site are used for grazing, mining, and storage and conveyance of municipal water supplies. Along Highway 93, an area of land approximately 1,200 ft wide adjacent to the site's western boundary is available for eventual development, open space, or highway right-of-way. The 259-acre DOE National Wind Technology Center is located adjacent to the northwestern corner of the BZ OU on lands transferred from the DOE Rocky Flats Project Office (RFPO). Preserved open space is the primary existing and proposed use of the lands immediately north (Boulder County and City of Boulder) and east (Cities of Broomfield and Westminster) of the site.

Areas within the BZ OU and adjacent privately owned lands west of the site have been permitted by the State and County for mineral extraction (primarily clay, sand, and gravel mining). Some irrigated and nonirrigated croplands, producing primarily wheat and barley, are located northeast of RFETS near the Cities of Broomfield, Lafayette, and Louisville; north of RFETS near Louisville and Boulder; and in scattered parcels adjacent to the eastern boundary of the site. Much of the rest of the land immediately adjacent to RFETS is used for cattle grazing.

To the south, several horse operations and small hay fields exist at present. However, a mixed-use residential and commercial development known as Vauxmont, within the City of Arvada, is proposed for an area immediately adjacent to the southern boundary of the site (USFWS 2004a). By 2020, DRCOG projects that the entire area south of the site will be developed, as well as areas to the southeast that are either not already developed or protected as open space (City of Westminster) around Standley Lake.

Planning is ongoing for possible upgrades to transportation systems in the area around RFETS. The Northwest Corridor Environmental Impact Statement (EIS) process, which began in 2003 and is expected to be complete in late 2006, is looking at whether transportation improvements are needed in the Northwest Corridor and, if so, what options are the most effective and desirable. The study area extends from the freeway systems in the vicinity of U.S. Highway 36 in the City and County of Broomfield to the freeway systems in the vicinity of State Highway 58, I-70, and C-470 to the south in Jefferson County. As of mid-2005, the original 70 alternatives had been narrowed to 8, plus the "No Action" alternative, including alternatives focused on construction of a new highway alignment and alternatives focused instead on improving existing highway and arterial networks. The existing highways involved include those immediately adjacent to RFETS to the east and south. If a new highway alignment is chosen, it would run near Indiana Street to the east of RFETS, with different options diverging near State Highway 72 to the southeast of the site.

2.8.3 Natural Heritage Resources

The Refuge Act identifies the following significant RFETS qualities:[8]

- The majority of the site has generally remained undisturbed since its acquisition by the government.
- The site preserves valuable open space and striking vistas of the Front Range mountain backdrop.
- The site provides habitat for many wildlife species, including a number of threatened and endangered species, and is marked by the presence of rare xeric tallgrass prairie plant communities.

The Colorado Natural Heritage Program (CNHP),[9] a research entity of the Nature Conservancy housed at Colorado State University's College of Natural Resources, assessed the BZ OU for its ecological value (CNHP 1994, 1995). CNHP concluded the site contains highly significant natural elements important for the protection of Colorado's natural diversity and encouraged DOE to take actions to protect and appropriately manage the site.

CNHP classifies the xeric tallgrass prairie plant community as very rare. The RFETS macrosite was identified by CNHP as the largest known remnant of xeric tallgrass prairie in Colorado, and probably the largest remaining parcel in all of North America (CNHP 1994, 1995). Most of the remaining xeric tallgrass prairie in Colorado is found in Boulder and Jefferson Counties in small, dispersed parcels. Less than 20 occurrences of the xeric tallgrass prairie are known worldwide. Approximately 1,800 acres of this xeric tallgrass prairie unit occurs within site boundaries.

The Great Plains riparian community, identified by CNHP as Great Plains riparian woodlands and riparian shrublands, is classified as rare and declining. Examples of this community are found in the Rock Creek, Walnut Creek, Woman Creek, and Smart Ditch drainages (CNHP 1994, 1995). Approximately 54 acres of this type (includes riparian woodland, willow riparian shrubland, and lead plant riparian shrubland) occurs within the site boundary.

The tall upland shrubland community is found on north-facing slopes primarily in the Rock Creek drainage and was identified by CNHP as a potentially unique shrubland community, possibly not occurring anywhere else. This community commonly occurs just above wetlands and seeps (CNHP 1994). Although the tall upland shrubland

[8] Chapter 3 of the Rocky Flats National Wildlife Refuge Final Comprehensive Conservation Plan (CCP) and EIS also contains detailed descriptions of the habitat communities (USFWS 2004a).

[9] The CNHP is an independent, multidisciplinary group of ecologists that gather information on rare species and habitats and maintain the Biological and Conservation Databases (designed by the Nature Conservancy). Using databases that provide site-specific information for given species and habitats, they are able to rank and prioritize areas representing the nation's natural biodiversity. Priorities can then be established for the protection of the most sensitive areas to help in determining land use options.

represents less than 1 percent of the total area of Rocky Flats, it contains 55 percent of the plant species on the site.

2.8.4 Cultural Resources

Two archeological surveys were conducted at RFETS, in 1989 and 1991. These surveys identified local points of interest in the BZ OU, such as Lindsay Ranch and an apple orchard. However, at that time, no sites or artifacts were found to be eligible for listing on the National Register of Historic Places (DOE 2000).

A survey of the IA OU was prepared in 1995 (AeroVironment 1995). The survey report concluded several facilities in the IA are of historic importance because of the role they played in the site's contribution to the Cold War. The State Historic Preservation Office (SHPO) agreed with these conclusions. Subsequent discussions with the SHPO determined how the historic information at the site would be recorded.

On January 16, 1998, 64 buildings and facilities at RFETS were included in a district that was formally added to the National Register of Historic Places. A Historic American Engineering Record (HAER) for the RFETS district was created using various reports, photographs, and drawings to document the history and significant contributions from 1953 to 1992 for the Rocky Flats Plant (DOE 1998). The HAER program was established in accordance with the 1935 Historic Sites Act (P.L. 74-292) and the 1966 National Historic Preservation Act (NHPA) (P.L. 89-665), as amended in 1980 (P.L. 96-515). The HAER program sets out to capture vanishing industrial and engineering treasures nationwide, in written historical reports. The RFETS district HAER was reviewed and accepted by the U.S. Department of Interior, National Park Service on January 22, 1999, and the HAER was transmitted to the Library of Congress. As a result of the National Park Service accepting the HAER, decontamination, decommissioning, and demolition of buildings within the historic district complied with the NHPA requirements.

A Cultural Resource Management Plan (CRMP) (SAIC 1996) was prepared that incorporated information from both the archeological and IA OU surveys and established guidelines regarding how to manage site cultural resources.

2.8.5 Property Rights

2.8.5.1 Subsurface Rights

The majority of RFETS is subject to subsurface property rights held by private owners. Extraction of subsurface minerals has occurred on or adjacent to the western area of the site for at least the last 60 years, and historically has included mining of coal, clay, and sand and gravel. Active permits currently exist for surface mining of sand, gravel, and clay in the northwest area of the BZ OU. Lafarge West, Inc. holds a permit to mine sand, gravel, and clay in Section 4, called the Bluestone Pit. Church Ranch holds a permit to mine sand, gravel, and clay in the NE ¼ of the SE ¼ of Section 9, the Rocky Flats Pit. Lakewood Brick & Tile Company holds a permit to mine clay in the NW ¼ of the SE ¼ of Section 9, called the Church Pit. No other mining permits are currently in place within the site boundaries. Ownership of mineral rights for the site is presented on Figure 2.22.

2.8.5.2 Rock Creek Reserve

Rock Creek Reserve was created in May 1999 through a designation by the U.S. Secretary of Energy and execution of a cooperative agreement between DOE and the U.S. Fish and Wildlife Service (USFWS) for management of Rock Creek Reserve's ecologically important resources. Approximately 850 acres of the northern BZ was designated as Rock Creek Reserve for purposes of protecting and preserving the important wildlife, cultural, and open space resources in this area. DOE retains jurisdiction of the area and is responsible for access controls. Under the cooperative agreement, USFWS manages the ecological resources. Most of the Rock Creek Reserve was part of several livestock ranches (most notably, the Lindsay Ranch) before DOE purchased the property.

In May 2001, DOE and USFWS published the Integrated Natural Resources Management Plan and Environmental Assessment (DOE/USFWS 2001). This plan outlines steps proposed for the next 5 years to provide for the stewardship of the natural resources of the Rock Creek Reserve (also known as the Rock Creek Fish and Wildlife Cooperative Management Area). In this plan, the Rock Creek Reserve was expanded to 1,793 acres to include the entire northern boundary of the BZ (Figure 2.2).

Within the Rock Creek Reserve are areas that have been permitted for mining. Thus, certain mineral rights, as discussed earlier, are being exercised. As noted above, a mining permit, called the Bluestone permit, was granted by the Colorado Division of Mining and Geology, and a zoning variance was passed by the Jefferson County Commissioners in 1995. The permit and variance included part of the area that became designated the Rock Creek Reserve. The portion of the Bluestone permit area lying within Rock Creek Reserve is located in the northwest, and includes approximately 250 acres, of which approximately 20 acres are permitted for mining. The remaining 230 acres of the permitted area are designated as a nonmining buffer area. Mining operations have not yet begun in this area.

2.8.5.3 Easements

The RFETS property is subject to easements and licenses granted by the U.S. government to third parties, primarily public utilities. A list of the existing easements and licenses is provided in Table 2.9, and the locations of these easements and licensed areas are illustrated on Figure 2.4. (The reference numbers in Table 2.9 correspond to the numbers on Figure 2.4.) The easements and licenses generally contain provisions for rights of access for the purposes of maintenance and operation.

2.8.6 Future RFETS Land Use

The Refuge Act designated Rocky Flats as Colorado's seventh National Wildlife Refuge. The designation will be effective upon achieving closure as defined in the Refuge Act, at which time jurisdiction of the areas of RFETS that become a wildlife refuge will be transferred to the U.S. Department of the Interior for Refuge purposes.

The purposes of the Refuge are as follows:

- Restoring and preserving native ecosystems;
- Providing habitat for and population management of native plants and migratory and resident wildlife;
- Conserving threatened and endangered species; and
- Providing opportunities for compatible scientific research.

The following land management actions or implications are expected:[10]

- Land ownership will remain with the United States; however, jurisdiction for certain portions of RFETS will be transferred from DOE to the U.S. Department of the Interior.
- The U.S. Department of the Interior, specifically USFWS, will administer the Refuge.
- The lands retained by DOE are expected to be managed consistent with the Refuge.
- Once designated as a National Wildlife Refuge, the transferred property will not be subject to annexation by any unit of general local government.
- The Refuge Act prohibits the United States from transferring any rights, title, or interest in land within the boundaries of Rocky Flats, except for the purpose of transportation improvements on the eastern edge of RFETS that is bordered by Indiana Street.
- It is anticipated that use of the land for residential, commercial, or industrial purposes will not occur, and that surface water and groundwater will not be used for potable water supplies. The land is not anticipated to be used as cropland, although the CCP allows for limited livestock grazing for the purpose of vegetation management.

2.9 Ecology

At an elevation of approximately 6,000 ft above MSL, the site contains a unique ecotonal mixture of mountain and prairie plant species resulting from the topography of the area

[10] See the Refuge Act for its specific requirements. This discussion is intended only as a brief overview of the Refuge Act requirements in relation to the anticipated future use of RFETS as a Refuge. Also, the website http://rockyflats.fws.gov provides routinely updated information on the Refuge.

and its proximity to the mountain front. The relatively undeveloped site provides numerous plant communities that are used by wildlife to satisfy habitat needs. Many of these plant communities are increasingly rare along the Front Range as urbanization continues to replace and fragment the remaining parcels of these plant communities. This section, which is largely a direct excerpt from the *Affected Environment* text in the CCP, provides a description of the vegetation, wildlife, and threatened and endangered species present at RFETS (USFWS 2004a).[11]

2.9.1 Vegetation

A diverse range of vegetation communities is found at RFETS (Table 2.10). Two of these vegetation communities, the xeric tallgrass grassland and the tall upland shrubland, are considered rare in the region. Other significant vegetation communities at RFETS include the riparian woodland, riparian shrubland, wetlands, mesic mixed grassland, xeric needle and thread grassland, reclaimed mixed grassland, and ponderosa pine woodland (Figure 2.23) (K-H 1997a, 1997b). Vegetation communities at RFETS have been grouped into Resource Management Zones. These zones generalize RFETS into three categories with similar wildlife habitat attributes and management requirements. The three management zones are xeric tallgrass grassland, wetlands and riparian corridors, and mixed prairie grassland.

2.9.1.1 Xeric Tallgrass Grassland Management Zone

<u>Xeric Tallgrass Grassland</u>

This rare plant community is found on the rocky plains in the western portions of the site, extending eastward along several fingerlike ridgelines (Figure 2.23). The xeric tallgrass grassland covers 1,568 acres and contains several different plant associations that include combinations of big bluestem *(Andropogon gerardii)*, little bluestem *(Andropogon scoparius)*, mountain muhly *(Muhlenbergia montana)*, sun sedge *(Carex. heliophila)*, Fendler's sandwort *(Arenaria fendleri)*, and Porter's aster *(Aster porteri)*. Other tallgrass prairie species include Indian-grass *(Sorghastrum nutans)*, prairie dropseed *(Sporobolus heterolepis)*, switchgrass *(Panicum virgatum)*, and needle-and-thread grass *(Stipa comata)*. Species richness is high; 295 species have been recorded within the xeric tallgrass community at the site, of which approximately 80 percent are native (K-H 2002c).

The xeric tallgrass grassland is believed to be a relict once connected to the tallgrass prairie hundreds of miles to the east (Essington et al. 1996; Nelson 2003). CNHP has found that much of the xeric tallgrass grasslands along the Colorado Front Range have been disturbed by urban development and agricultural conversion over the last century. In addition, aggressive weed species, such as cheatgrass *(Bromus* ssp.*)*,

[11] The majority of text in this Ecology section is taken directly from the CCP (USFWS 2004a). However, the text was modified in several cases to be consistent with findings from vegetation surveys documented in the 2001 Annual Vegetation Report for RFETS (K-H 2002c) and wildlife surveys documented in the 2000 Annual Wildlife Survey for RFETS (K-H 2001). In addition, Latin names were added for plant and animal species referenced.

Japanese brome *(Bromus japonicus)*, and diffuse knapweed *(Centaurea diffusa)*, have degraded many areas of this community throughout the region (Essington et al. 1996), as well as at RFETS. CNHP believes that the xeric tallgrass grassland community exists in fewer than 20 places globally and that RFETS has the largest example of this community remaining in Colorado and perhaps North America. CNHP ranks this community as imperiled within the state (Essington et al. 1996).

The xeric tallgrass grassland community is composed of several subcommunities (Nelson 2003). One of these subcommunities was identified by ESCO Associates Inc. (ESCO) during a 5-year evaluation of bluestem-dominated grasslands in the RFETS area. This study found that the major distinguishing feature of what ESCO calls the rare "Rocky Flats Bluestem Grassland" community is the abundance of big bluestem with little bluestem, mountain muhly, and Porter's aster (Figure 2.23). While big and little bluestem are characteristic of Midwestern tallgrass prairies, mountain muhly and Porter's aster are characteristic of mountain environments. This unusual combination of mountain and plains grassland species in a consistent and recurring pattern across the Rocky Flats alluvial surface, along with evidence of exceptional stability, makes this vegetation community a rare, if not unique, resource (ESCO 2002).

In 2001, high winds deposited several inches of sand on xeric tallgrass grassland areas adjacent to existing gravel mines in the northwestern corner of the site (Figure 2.24). This sand buried most of the native vegetation and was soon colonized by sunflower *(Helianthus pumilus)*, a native annual weedy species, as well as noxious weeds such as diffuse knapweed, Russian thistle *(Salsola iberica)*, and kochia *(Kochia scoparia)*.

2.9.1.2 Wetlands and Riparian Corridors Management Zone

Riparian Woodland

The riparian woodland community is characterized by a diverse mixture of plains cottonwood *(Populus deltoides)*, peachleaf willow *(Salix amygdaloides)*, and Siberian elm *(Ulmus pumila)*, with an understory of various shrubs such as coyote willow *(Salix exigua)*, false indigo (*Amorpha fruticosa*), and snowberry *(Symphoricarpos occidentalis)*. Covering 28 acres, it is found primarily along the RFETS drainage bottoms, with the most significant stand occurring in the Rock Creek drainage (Figure 2.23) (CNHP 1994; Essington et al. 1996; K-H 1997a, 1997b; PTI 1997a).

The most significant threat to the riparian woodland community is from exotic species such as Siberian elm, Canada thistle *(Cirsium arvense)*, musk thistle *(Carduus nutans)*, smooth brome *(Bromus inermis)*, and Kentucky bluegrass *(Poa pratensis)*. Preservation of this woodland community depends on the preservation of associated streamflow (Essington et al. 1996; PTI 1997a).

Riparian Shrubland

Riparian shrubland forms extensive, dense thickets of shrubs along the stream bottoms. This community covers 41 acres throughout RFETS (Figure 2.23). It is dominated by coyote willow and false indigo and generally has an understory consisting of Canada thistle (a noxious weed), meadow fescue *(Festuca pratensis)*, Canada bluegrass *(Poa compressa),* Baltic rush *(Juncus balticus),* and various sedges (Kettler et al. 1994; USACE 1994; K-H 1997b).

<u>Tall Upland Shrubland</u>

Tall upland shrubland occurs on 34 acres of north-facing slopes above seeps and along streams, primarily within the Rock Creek drainage (Figure 2.23). The tall upland shrubland consists of a rare association of hawthorn *(Crataequs erythropoda),* chokecherry *(Prunus virginiana)*, and occasionally wild plum *(Prunus americana).* This shrubland is associated with groundwater seeps that form at the contact of the RFA and the underlying, relatively impermeable Arapahoe Formation. The herbaceous understory contains a number of species that are restricted to the cool, shaded microhabitat provided by the canopy. Understory species include Fendler waterleaf *(Hydrophyllum fendleri),* spreading sweetroot *(Osmorhiza chilensis),* anise root *(Osmorhiza longistylis),* carrionflower greenbriar *(Smilax herbacea)*, fragile fern *(Cystopteris fragilis)*, Colorado violet *(Viola scopulorum)*, Rydberg's violet *(Viola rydbergii)*, and northern bedstraw *(Galium septentrionale).* Although the tall upland shrubland represents less than 1 percent of the total area of RFETS, it contains 55 percent of the plant species on the site (DOE/USFWS 2001). This shrubland community is believed to be rare and may not occur anywhere else (Essington et al. 1996; DOE/USFWS 2001).

<u>Other Shrubland</u>

Other shrubland communities include short upland shrubland and savannah shrubland, covering 70 acres primarily in the Rock Creek drainage (Figure 2.23). Short upland shrubland is characterized by stands of snowberry and occasional Wood's rose *(Rosa woodsii)* and is often found in association with wet meadows and other wetland or riparian communities. Savanna shrubland occurs in drier areas where scattered shrubs are interspersed with grasslands. Three-leaf sumac *(Ruhus trilobata)* is the predominant shrub in this community (K-H 1997a).

2.9.1.3 Wetland Communities

Wetland communities cover 406 acres of the site and play an important role in sustaining the diverse vegetation and habitat types found on the site. The most significant wetland complexes at RFETS are the seep-fed wetlands along the hillsides of the Rock Creek drainage and the Antelope Springs complex in the Woman Creek drainage. These wetlands are significant because they have the largest contiguous areas and the most complex plant associations (PTI 1997a).

A sitewide wetlands delineation and characterization study was conducted by the USACE in 1994 (USACE 1994) and coordinated with EPA, the Colorado Division of Wildlife, the USDA SCS, and the Regulatory Branch of the USACE. The study, which utilized the USFWS classification system and the 1987 USACE Wetland Delineation Manual as guidelines for the wetlands delineation process, provided the basis for the sitewide wetlands map presented on Figure 2.25.

Three main wetland types (tall marsh, short marsh and wet meadow) are found at the site. These occur in streamside areas along the valley floors and near the seeps and springs that occur along many of the hillsides. Each wetland type is described below.

Tall Marsh Wetland

Tall marsh wetlands generally occur along ponds and ditches and in persistently saturated seeps (Figure 2.23). Covering 31 acres of the site, these wetlands are dominated by cattails *(Typha ssp*.), bulrushes (*Scirpus ssp*), and associated forbs such as watercress *(Nasturtium officinale),* showy milkweed *(Ascelepias speciosa),* swamp milkweed *(Ascelepias incarnata),* and Canada thistle. Antelope Springs in the Woman Creek drainage is the best example of a saturated slope wetland and tall marsh community at RFETS.

Short Marsh Wetland

The short marsh wetlands cover 121 acres at RFETS, and are commonly associated with seasonally inundated or saturated areas, such as hillside seeps (Figure 2.23). Prevalent species include Nebraska sedge (*Carex nebrascensis*), Baltic rush, and spike rush (*Eleocharis ssp.*), as well as forbs such as watercress and speedwell (*Veronica ssp.*).

Wet Meadow Wetland

These seasonally saturated wetlands occupy 254 acres on the perimeter of saturated wetlands and contain elements of both the short marsh wetland and upland mixed grassland communities (Figure 2.23). Prevalent species include redtop *(Agrostis stolonifera),* prairie cordgrass *(Spartina pectinata),* and solid stands of Canada bluegrass and western wheatgrass *(Agropyron smithii).* Other species commonly found in this community include common milkweed *(Asclepias speciosa),* wild iris *(Iris missouriensis),* Canada thistle, dock (*Rumex ssp*.), and occasionally arnica *(Arnica fulgens*) (Nelson 2003).

2.9.1.4 Mixed Prairie Grasslands Management Zone

Mesic Mixed Grassland

The mesic mixed grassland community is the largest vegetation community at RFETS, covering 2,199 acres across the broad ridges, hillsides, and valley floors throughout the site and the rolling plains in the eastern portions of the site (Figure 2.23). This community is characterized by western wheatgrass, blue grama *(Bouteloua gracilis),* side-oats grama *(Bouteloua curtipendula),* prairie junegrass *(Koeleria pyramidata),* Canada bluegrass, Kentucky bluegrass, green needlegrass *(Stipa virigula),* and little bluestem. This grassland occurs on clay loam soils having relatively higher soil moisture content than other upland areas. The higher moisture results from subirrigation from the coarse alluvial soils, snow accumulation, and protection from wind (DOE 1997).

The mesic mixed grassland is very important to wildlife species including grassland birds, small mammals, and larger mammals such as mule deer. The quality of mesic mixed grassland varies considerably across the site. In the western parts of the site, this community has been degraded by diffuse knapweed, while some areas in the eastern portion of the site have been degraded by weed species such as Japanese brome, alyssum *(Alyssum minus)*, and musk thistle *(Carduus nutans)* (PTI 1997b).

Xeric Needle and Thread Grassland

Several patches of xeric grassland dominated by needle-and-thread grass occur in the eastern half of RFETS. These patches cover 187 acres (Figure 2.23). Other dominant grass species include New Mexico feathergrass *(Stipa neomexicana)*, Canada bluegrass, Kentucky bluegrass, and Japanese brome (Nelson 2003). This grassland occurs primarily on the eastern extensions of the Rocky Flats pediment that is characterized by very cobbly, sandy loam soils. Although not as cobbly, these soils are very similar to the soils that support the xeric tallgrass grassland community (K-H 1997b; PTI 1997a). The largest expanse of needle-and-thread grassland at RFETS occurs along the ridgetop north of the former East Access Road.

Reclaimed Mixed Grassland

Reclaimed mixed grassland covers 640 acres, primarily in the southeastern portion of the site that was formerly cultivated for agriculture (Figure 2.23). Most of these areas have been reseeded with a mixture of smooth brome and intermediate wheatgrass *(Agropyron intermedium)*, both introduced species. Other common species include crested wheatgrass *(Agropyron cristatum)*, sweetclover (*Melitotus ssp.*), and field bindweed *(Convolvulus arvensis*) (K-H 1997b).

Short Grassland

This grassland is typified by buffalograss *(Buchloe dactyloides)* and blue grama, both short grass prairie species. Ten acres of this community are found on the site (K-H 1997b), typically in relatively small, isolated areas near the RFETS eastern boundary at Indiana Street.

Ponderosa Pine Woodland

Isolated patches of ponderosa pine woodland cover 9 acres in the uppermost reaches of the Rock Creek and Woman Creek drainages near the western edge of the site. These scattered pines represent an eastward extension of the nearby foothills forests. While much of the understory is similar to the adjacent grassland communities, other associated plants are more likely to occur in foothills environments (DOE 1997).

Disturbed and Developed Areas

Disturbed and developed areas consist of existing or former facilities associated with the previous use of the site. They include roads, landfills, dams, and other facilities, such as groundwater treatment systems. They also include former facilities that have been revegetated with native and introduced grass species.

2.9.1.5 Noxious Weeds

Noxious weeds are exotic, aggressive plants that invade native habitat and cause adverse economic or environmental impacts. Since 1990, the site has experienced a large increase in noxious weeds (DOE 1997). At RFETS, the noxious weed species with the greatest potential to degrade the native plant communities and that are the most difficult to control include diffuse knapweed, musk thistle, Dalmatian toadflax *(Linaria dalmatica),* and Canada thistle. Other increasingly problematic weeds are downy brome (cheatgrass) *(Bromus tectorum),* field bindweed, and jointed goatgrass *(Aegilops cylindrica)* (Lane 2004). Diffuse knapweed, an aggressive tumbleweed, is currently given highest control priority. Canada thistle is common in and around most of the wetlands, musk thistle is found across mesic grasslands, and Dalmatian toadflax is common in xeric grasslands and other areas (Figure 2.23).

Prioritized noxious weed lists and select weed control measures are found in the 2002 Annual Vegetation Management Plan (K-H 2002d). The three most abundant noxious weeds identified during 2001 mapping were diffuse knapweed (1,957 acres) (Figure 2.26), common mullein *(Verbascum thapsus)* (1,357 acres) (Figure 2.27), and musk thistle (869 acres) (Figure 2.28) (Table 2.11) (DOE/USFWS 2001; K-H 2002d).

2.9.1.6 Rare Plants

No federally listed plant species, such as the Ute ladies'-tresses orchid *(Spiranthes diluvialis)* or Colorado butterfly plant *(Gaura neomexicana ssp. coloradensis),* are known to occur at RFETS. Aside from the rare xeric tallgrass prairie and tall upland shrubland communities, RFETS also supports populations of four plant species that are listed as rare or imperiled by CNHP. These species are the mountain-loving sedge *(Carex oreocharis),* forktip three-awn *(Aristida basiramea),* carrionflower greenbriar, and dwarf wild indigo *(Amorpha nana)*. Forktip three-awn primarily occurs in previously disturbed sites near the western edge of the IA OU. The other three species occur primarily along the pediment slopes in the Rock Creek drainage (K-H 2002c).

2.9.1.7 Fire History

Historical documentation indicates grasslands in the RFETS area have been subjected to lightning- and human-caused fires for thousands of years (DOE 1999). These fires likely played a major role in promoting native vegetation growth and diversity (DOE 1999). Since 1972, wildfires have not been allowed to burn and only one controlled burn has been conducted in the grasslands at RFETS. As a result, a fuel load of dead vegetation has been building up in the grasslands at the site for at least

30 years. This buildup of dead vegetation has contributed to an invasion of noxious weeds on the site, particularly in the last 10 years (DOE 1999). Seven wildfires have been documented on the site since 1993. In addition, a prescribed burn was conducted on April 6, 2000. These grassland fires are summarized in Table 2.12.

2.9.2 Wildlife Resources

Many areas of the site have remained relatively undisturbed for the past 30 to 50 years, allowing them to retain diverse habitat and associated wildlife. These wildlife communities are supported by the regional network of protected open space that surrounds the site on three sides, buffering wildlife habitat from the surrounding urban development.

2.9.2.1 Mammals

One of the most abundant and conspicuous mammal species at RFETS is the mule deer *(Odocoileus hemiomus).* A resident herd of approximately 160 individuals inhabits the site. While mule deer distribution varies by season, they appear to have a general preference for the following areas:

- Open grasslands of the upper Rock Creek drainage;
- Shrublands of the lower Rock Creek drainage;
- Grasslands of the upper Walnut Creek drainage;
- Hillsides above lower Walnut Creek drainage;
- Riparian bottomlands around Woman Creek and Antelope Springs; and
- Grasslands below the pediment in the Smart Ditch drainage.

In the spring, mule deer exhibit an affinity for woody habitat and secondarily for grasslands. In the summer, deer use is more generally divided among different habitats. In the fall, mule deer primarily use woody habitats, with grasslands also being important. In the winter, mule deer are commonly observed in grasslands and tall upland shrublands (K-H 2001).

Other ungulates also use the site. Whitetail deer *(Odocoileus virginianus)* have become more common at the site and are often observed in company with mule deer. RFETS is in Colorado Division of Wildlife (CDOW) Game Management Unit (GMU) #38 and is adjacent to GMU #29, which collectively make up the Boulder deer herd. American elk *(Cervus elahus)* visit the site, but are not resident (DOE 1997). In 2003, 11 cow elk were observed with 9 calves in the Rock Creek drainage (Wedermyer 2003).

Other mammals observed at RFETS include the desert cottontail *(Sylvilagus audubonii),* white-tailed jackrabbit *(Lepus townsendii),* black-tailed jackrabbit *(Lepus californicus),* muskrat *(Ondatra zibethicus),* and porcupine *(Erethizon dorsatum)*. Muskrats generally occur in and around the ponds, while porcupine populations are limited to the shrubland and ponderosa pine habitats in the upper Rock Creek drainage (DOE 1997). Black-tailed prairie dogs *(Cynomys ludovicianus)* inhabit the site in limited numbers and are discussed in greater detail below. Numerous small mammal species, such as the water shrew *(Sorex palustris)*, harvest mouse *(Reithrodontomys megalotis)*, deer mouse *(Peromyscus maniculatus)*, pocket mouse *(Perognathus flavus)*, meadow vole *(Microtus pennsylvanicus)*, prairie vole *(Microtus ochrogaster)*, and Mexican woodrat *(Neotoma mexicana)*, inhabit certain vegetation community types at Rocky Flats. The PMJM *(Zapus hudsonius preblei)*, a threatened species, is described in Section 2.9.3. Various species of bats have been observed at RFETS including the western small-footed myotis *(Myotis ciliolabrum)*, the little brown myotis *(Myotis lucifugus)*, the hoary bat *(Lasiurus cinereus)*, and the big brown bat *(Eptesicus fuscus)* (K-H 1998). These bats are found in a variety of habitats including dwellings, rock outcrops, and trees.

Two commonly observed carnivore species at RFETS are the coyote *(Canis latrans)*, which occurs throughout the site, and raccoon *(Procyon lotor)*, which is often seen in the IA OU and near watercourses. Typically at RFETS, three to six coyote dens support an estimated 14 to 16 individuals at any given time (K-H 2001).

Twenty-two coyote dens used between 1991 and 2002 have been identified at RFETS. The coyote dens generally occur on hillsides near watercourses. Six dens were active in 2002. One active den was located in the upper Rock Creek drainage, two were located on the slopes above either side of Walnut Creek near Indiana Street, one was near Pond D-1, one was near Antelope Springs, and one was in the upper South Woman Creek drainage (Nelson 2003). Other carnivores include striped skunk *(Mephitis mephitis)*, gray fox *(Urocyon cinereoargenteus)*, red fox *(Vulpes vulpes)*, long-tailed weasel *(Mustela frenata)*, American badger *(Taxidea taxus)*, and mink *(Mustela vison)*. Black bear *(Ursus americanus)* and mountain lion *(Felis concolor)* tracks are occasionally seen at the site (K-H 2000a, 2001).

<u>Black-Tailed Prairie Dog</u>

The black-tailed prairie dog is a controversial species in terms of U.S. conservation activities (CDOW 2003). The prairie dog is often described and disputed as a “keystone species” because it has a large effect on community structure or ecosystem function (Power et al. 1996; CDOW 2003).

In August 2004, USFWS removed the prairie dog from consideration as a candidate species under the Endangered Species Act (ESA) (USFWS 2004b). Candidate species are plants and animals for which USFWS has sufficient information on their biological status to propose them as endangered or threatened under the ESA, but for which development of a proposed listing regulation is precluded by other higher-priority listing activities. Candidate species receive no statutory protection under the ESA (USFWS 2002).

Regardless of its status as a keystone species, prairie dogs play an important role in grassland ecosystems. Several studies found that prairie dogs alter plant species’ composition and structure. Typically, areas occupied by prairie dogs have greater cover and abundance of perennial grasses and annual forbs compared to nonoccupied sites (Whicker and Detling 1988; Witmer et al. 2002). Prairie dogs can contribute to overall landscape heterogeneity, affect nutrient cycling, and provide nest sites and shelter for wildlife such as rattlesnakes and burrowing owls (Whicker and Detling 1988). However, prairie dogs can also denude the surface by clipping aboveground vegetation and contributing to exposed bare ground by digging up roots (Kuford 1958; Smith 1967) and are susceptible to and can spread Sylvatic plague.

Three black-tailed prairie dog colonies, comprising 112.8 acres of grasslands, were mapped at RFETS in 2000. These colonies are in similar locations as in 1991 (Ebasco 1992). Mapping conducted in 2002 shows a smaller area of colonies. This reflects plague outbreaks since 2000 that eventually reduced the active colonies to an area of approximately 10 acres (Stone 2004). Mapping conducted in 2005 shows the colonies in generally the same locations with some expansions at a few locations. There is one previous location where they no longer occur and another location where a colony now exists (Figure 2.29).

The site contains approximately 2,460 acres of potential prairie dog habitat based on the following soil, vegetation, and slope attributes that prairie dogs are known to prefer (Clippinger 1989):

- 30- to 90-percent herbaceous cover;
- 2- to 10-inch vegetation height;
- Slopes less than 20 percent (prefer less than 10 percent); and
- Rock-free soils with less than 70 percent sand content.

2.9.2.2 Birds

The most commonly observed raptors at RFETS are the red-tailed hawk *(Buteo jamaicensis)*, great horned owl *(Bubo virginianus)*, and American kestrel *(Falco sparverius)*. Other less abundant raptors include Swainson's hawk *(Buteo swainsoni)*, ferruginous hawk *(Buteo regalis)*, prairie falcon *(Falco mexicanus)*, and long-eared owl *(Asio otus)*. Most raptor species use riparian woodlands or tall upland shrublands for nesting and roosting habitat and forage in all habitats at the site.

Over 185 species of migratory birds have been recorded at RFETS, of which approximately 75 are believed to breed at the site. Of the estimated 100 neotropical migrants (migratory birds that breed north of the U.S./Mexico border and winter south of the border) (K-H 1999), approximately 45 are confirmed or suspected breeders at the site.

Commonly observed bird species in wetland habitats include the red-winged blackbird *(Agelaius phoeniceus)*, song sparrow *(Melospiza melodia)*, common yellowthroat *(Geothlypis trichas)*, and common snipe *(Gallinago gallinago)*. Common birds in riparian woodland areas include the northern oriole *(Icterus galbula)*, American goldfinch

(Carduelis tristis), house finch *(Carpodacus mexicanus)*, and yellow warbler *(Dendroica petechia)*. The tall upland shrubland habitat is inhabited by the song sparrow, rufus-sided towhee *(Pipilo maculatus*), black-billed magpie *(Pica hudsonia)*, yellow-breasted chat *(Icteria virens)*, and black-capped chickadee *(Poecile atricapilla).* Common grassland birds include the vesper sparrow *(Pooecetes gramineus)*, western meadowlark *(Sturnella neglecta)*, grasshopper sparrow *(Ammodramus savannarum)*, and mourning dove *(Zenaida macroura)* (DOE 1997). The reclaimed mixed grassland provides habitat for birds such as the western meadowlark and vesper sparrow (K-H 1999).

Several waterfowl and wading bird species use the RFETS ponds. The most common waterfowl is mallard *(Anas platyrhynchos)* (Ebasco 1992; K-H 2000a). Other species are common during certain seasons such as Canada goose *(Branta canadensis)* and lesser scaup *(Aythya affinis)* (K-H 2000a). Great blue heron *(Ardea herodias)* feed in mudflats and short marshlands, while double-crested cormorant *(Phalacrocorax auritus)* are common summer residents. Species documented as breeding at the site include pied-billed grebe *(Podilymbus podiceps)*, American coot *(Fulica americana)*, mallard, and blue-winged teal *(Anas discors)* (K-H 2000a).

<u>Plains Sharp-Tailed Grouse</u>

The site and surrounding areas contain potential habitat for the plains sharp-tailed grouse *(Tympanuchus phasianellus)*. The grouse is not known to have occurred at RFETS prior to 2003 (DOE 1997). The City of Boulder Open Space and Mountain Parks Department, along with Boulder County Parks and Open Space and CDOW, have initiated a sharp-tailed grouse reintroduction program on joint City/County-owned open space land north of the site. Approximately 25 individuals were transplanted to the open space area in 2003, while several more are planned to be reintroduced in the future (Brennan 2003). Several of the transplanted individuals are believed to have used RFETS grasslands (Wedermyer 2003).

According to the CDOW Plains Sharp-Tailed Grouse Recovery Plan (CDOW 1992), grouse use different habitats seasonally with extensive use of grassland and grassland-low shrub transition zones. Riparian areas and wooded draws are important winter habitat. Reasons for the decline of sharp-tailed grouse include land cultivation, livestock grazing, and fire control. Other threats to grouse include urban development and alteration of habitat by weed infestation (Gershman 1992).

2.9.2.3 Reptiles and Amphibians

In general, reptiles and amphibians are found in small numbers at the site due to an absence of suitable habitat. The most common reptiles are the bullsnake *(Pituophis melanoleucus)*, yellow-bellied racer *(Coluber constrictor)*, plains garter snake *(Thamnophis radix)*, and prairie rattlesnake *(Crotalus viridis)*. All of these species occur in the open grassland habitats, although the plains garter snake typically lives close to water bodies. Other reptiles include the short-horned lizard (*Phynosoma douglassi)* in open grasslands and the western painted turtle *(Chrysemys picta)* in ponds (DOE 1997).

The most abundant amphibian at RFETS is the boreal chorus frog *(Pseudacris triseriatus maculata)*, which breeds in water bodies throughout the site. The northern leopard frog *(Rana pipiens)* is less common and is found only in permanent water bodies such as ponds (DOE 1997). The boreal chorus frog is relatively abundant in the streams and wetlands at Rocky Flats (K-H 2000a). Other amphibians include the bullfrog *(Rana catesbeiana)*, Woodhouse's toad *(Bufo woodhousii)*, plains spadefoot *(Spea bombifrons)*, and tiger salamander *(Ambystoma tigrinum)* (DOE 1997).

2.9.2.4 Aquatic Species

Each of the primary drainages at the site contains pond and stream habitats, varying with the amounts of habitat modification and seasonal water flows available. Streams at RFETS are flow-limited; however, in general, the upper reaches of the creek drainages flow perennially while the downstream reaches have intermittent flows. The low and irregular flows in the Rock, Walnut, and Woman Creeks limit the amount of quality habitat for aquatic fauna and therefore limit the number and variety of aquatic species at RFETS. However, aquatic fauna are found in both stream and pond habitats. Past sampling results (Ebasco 1992; DOE 1996; Exponent 1998; AAI 2003) have shown that the macroinvertebrate stream communities have a moderate amount of diversity, and are comprised mostly of hardy and tolerant species. Aquatic macroinvertebrates include a variety of fauna such as insects and other arthropods, worms, and mollusks including clams and snails. The dominant macroinvertebrates in each stream are similar, with midges *(Chironomidae)* and black flies *(Diptera)* being the most common organisms in Walnut and Rock Creeks, and aquatic worms *(Oligochaeta)* being the most common in Woman Creek. Other common taxa found within all three streams include mayfly larvae *(Ephemeroptera)*, scuds *(Amphipoda)*, and snails *(Gastropoda)*. Stonefly larvae have been found in Rock and Woman Creeks, while populations of caddisflies *(Tricoptera)* and damselfly larvae *(Odonata)* have been found in Walnut Creek (AAI 2003).

Macroinvertebrate community sampling has also been performed in nine retention ponds in the Walnut Creek drainage and in two retention ponds in the Woman Creek drainage (Ebasco 1992; DOE 1995, 1996; AAI 199 8; WWE 2003). A variety of taxa and abundances were found in the ponds. Aquatic worms and midges were the most common organisms found in all the ponds (DOE 1996, 1997). A larger variety of taxa including mayflies, damselflies, and snails were found in the A- and B-Series Ponds in the Walnut Creek drainage. Pond A-1 had the greatest species richness of benthic macroinvertebrates found on RFETS. The Woman Creek drainage detention ponds were not found to support a wide variety of organisms besides midges and aquatic worms (DOE 1996). Large macroinvertebrates such as crayfish (Order *Decapoda*, Family *Cambaridae*) and snails are found in both streams and ponds. All macroinvertebrates are important prey for other fish, waterfowl, and mammal species.

Fish abundance and distribution in Walnut, Woman, and Rock Creeks are limited due to the lack of permanent water (AAI 2003). There is a larger variety of species found in the retention ponds of the drainages, which is largely due to the introduction of non-native fish species such as rainbow trout *(Salmo gairdneri)*, carp *(Cyprinus carpio)*, bass

(Micropterus spp.*)*, and goldfish *(Carassius auratus)* into some of the Rock, Walnut, and Woman Creek impoundments and retention ponds.

The only fish found in Walnut and Rock Creeks was fathead minnows *(Pimephales promelas)*. Sampling of Woman Creek resulted in the findings of creek chubs *(Semotilus atromaculatus)*, fathead minnows, largemouth bass *(Micropterus salmoides)*, stonerollers *(Campostoma anomalum)* and carp *(Cyprinus carpio*) (Ebasco 1992). A single specimen of longnose dace *(Rhinichthys cataractae)* was also found in Woman Creek during another sampling occasion (AAI 2003).

Fish community sampling performed in the detention ponds located within the Rock, Walnut, and Woman Creek drainages has resulted in finding a variety of both native and introduced fish species. Fathead minnows, white suckers *(Catostomus commersoni)*, and largemouth bass were found in Lindsay Pond, which is located in the Rock Creek drainage. Fathead minnows, golden shiners *(Notemigonus crysoleucas)*, and largemouth bass were found in the A-Series Ponds located in the Walnut Creek drainage, while only fathead minnows were found in the B-Series Ponds. Goldfish *(Carassius auratus)* were found in an isolated pond in the headwaters of the Walnut Creek drainage. The fish species found in the retention ponds in the Woman Creek drainage were fathead minnows, creek chubs, green sunfish *(Lepomis cyanellus)*, golden shiners, white suckers, and largemouth bass (Ebasco 1992).

Each of the primary drainages at the site contains a variety of pond and stream habitats, varying amounts of habitat modification, and seasonal water flows. According to the Colorado Vertebrate Ranking System (CDOW 2001), the Iowa darter *(Etheostoma exile)* and common shiner *(Luxilus cornutus)* rank high enough to merit reevaluation, and the redbelly dace *(Phoxinus eos)* is potentially imperiled. Threats to these species include extirpation through habitat degradation (such as siltation, pollution, and/or bank destabilization), effects of urbanization, and predation by introduced non-native fish.

<u>Native Fish Restoration</u>

The 2001 Rock Creek Reserve Integrated Natural Resources Management Plan (DOE/USFWS 2001) called for the establishment of native fish populations within the Rock Creek drainage. Rock Creek supports favorable habitat for native fish such as the common shiner and northern redbelly dace. Monitoring during the drought of 2002 demonstrated that Rock Creek flows remain consistent in dry years.

Native fish restoration efforts began in 2002, when largemouth bass *(Micropterus salmoides)* and other non-native fish were removed from the Lindsay Ponds with Rotenone (a pesticide). In June and August 2003, common shiner and northern redbelly dace were introduced to the Rock Creek drainage, with the intention of establishing a new population of these rare and declining native fish species (Rosenlund 2003).

2.9.2.5 Wildlife Species of Special Concern

In addition to federally listed wildlife species described in Section 2.9.3, RFETS has been known to support numerous species with special status designated by CDOW because of their rare or imperiled status. The western burrowing owl *(Athene cunicularia)* has been observed in grasslands, and the ferruginous hawk has been observed in riparian woodlands and open grasslands (PTI 1997b; DOE 1997).

2.9.2.6 Wildlife Corridors

While RFETS is surrounded on three sides by major roads, many wildlife species move between the site and habitat in surrounding areas. However, movement corridors between the site and adjacent lands are not well defined. Movement of most terrestrial species occurs along broad areas where disturbance and barriers to movement are minimized (Howard 2003; Wedermyer 2003). In general, mule deer and elk use the xeric grasslands in the western portion of the site as a travel corridor to access grasslands west of Highway 93 and the foothills.

On the western side of RFETS, east-west movement across Highway 93 can be impeded by the South Boulder Diversion Canal and mining areas. Given these barriers, the most likely areas for wildlife movement are the open lands in the upper Rock Creek and upper Woman Creek areas between the mining areas (on land owned by the State of Colorado) and the West Access Road.

Prairie dogs cross Highway 128 in the northeastern corner of RFETS, to access other colonies on adjacent open space lands. Otherwise, north-south prairie dog movement across Highway 128 does not likely occur at any specific location. The Rock Creek drainage along the highway is impeded by the highway embankment and the culverts for the creek are too small for use by larger species of mammals. Likewise, the eastern portion of the site is open in most places and wildlife moves across a broad front, although the Walnut Creek and Woman Creek drainages provide natural corridors for east-west movement for small and mid-size mammals across Indiana Street.

Most deer on RFETS do not migrate off site and elk periodically descend from the foothills and enter RFETS from the west. In spring 2003, several cow elk used the Rock Creek drainage as a calving ground (Wedermyer 2003). The behavior of other species is less known.

2.9.3 Federal Threatened and Endangered Species

The site supports one wildlife species, the PMJM, listed as threatened or endangered under the ESA. In addition to the PMJM, bald eagles occasionally forage at the site. Both the PMJM and bald eagle are listed as threatened. As discussed in Section 2.9.2, the black-tailed prairie dog is no longer listed as a candidate species (USFWS 2004b).

2.9.3.1 PMJM

Listed by USFWS as a threatened species in 1998, the PMJM occurs in habitat adjacent to streams and waterways along the Front Range of Colorado and southeastern Wyoming. The PMJM occurs in every major creek drainage on the site (Figure 2.30). The PMJM also has been found in wetlands and shrubland communities adjacent to the Rock Creek and Woman Creek drainages. Single PMJM were also caught along Smart Ditch in 1993 and 2001 (K-H 2002e). From 1998 to 2000, intensive radiotelemetry studies of PMJM were conducted along Rock, Walnut, and Woman Creeks. Therefore, PMJM distribution, movement patterns, and habitat preferences on RFETS are well understood. A PMJM Protection Plan was created by DOE and areas mapped under this plan have been adopted by USFWS with some revisions (USFWS 2004c).

In general, PMJM are restricted to streamside (riparian) areas with an adjacent narrow band of grasslands (Armstrong et al. 1997). Habitat contains two components: riparian and upland. Riparian habitat is thick, multistrata vegetation consisting of shrubs and trees as an overstory and thick herbaceous vegetation as understory. Uplands are composed of thick grasslands with scattered upland shrubs.

The three drainages where PMJM are found contain varying habitat characteristics. Rock Creek contains narrow, but largely contiguous, stretches of dense riparian shrubs and trees. Walnut Creek has fragmented habitat composed of three isolated sections: the A-Series Ponds, the B-Series Ponds, and Lower Walnut Creek. Woman Creek is characterized by contiguous, narrow riparian vegetation similar to Rock Creek, but has a shorter stream reach where habitat occurs.

Based on radiotelemetry, PMJM movements were associated with riparian habitats and individuals rarely traveled far from a stream. Table 2.13 presents a summary of telemetry endpoints. Most movements follow riparian corridors. Over the 3 years of radiotelemetry studies at RFETS, 93 percent of all points were within 48 m of water and 66 percent were within 16 m (K-H 2001). Individuals traveling away from a pond or stream were typically found in the dense vegetation associated with hillside seeps. During the 3 years of study, only one mouse was observed traveling overland between drainages (K-H 1999, 2000b, 2001). PMJM were observed using aboveground nests along the riparian upland habitat edge (Ryon 2001).

Continued study of this species may change the understanding of their habitat needs and associations. In 2003, USFWS designated critical habitat for the PMJM. The critical habitat did not include any of the drainages at RFETS because the site is to become a Refuge (USFWS 2003).

In March 2004, USFWS initiated a status review of the PMJM based on two petitions to remove the mouse from federal protection under the ESA. When the status review is finished, USFWS will issue a finding regarding whether the subspecies should remain listed or should be proposed for delisting (USFWS 2004d). However, until the status review and finding are finalized, USFWS will continue to manage the PMJM as a threatened species in accordance with existing laws and policies, and the Comprehensive

Risk Assessment (CRA) will address the PMJM separately from all other wildlife receptors.

2.9.3.2 Bald Eagle

The bald eagle *(Haliaeetus leucocephalus)* occasionally forages at RFETS although no nests have been identified. An active nest is located east of the site near Standley Lake. Eagles feed primarily on fish and waterbirds but also on small mammals and mammal carcasses (DOE/USFWS 2001). The bald eagle was federally listed as endangered in 1967 and was downlisted to threatened in 1994.

2.9.3.3 Plant Species

No federally listed plant species are known to occur at RFETS. While many of the riparian and wetland communities support potential habitat for the Ute ladies'-tresses orchid and Colorado butterfly plant, these species are not known to occur at the site (ESCO 1994). Vegetation at RFETS includes several rare and sensitive plant communities. These include the xeric tallgrass grassland, tall upland shrubland, riparian shrubland, mountain-loving sedge, forktip three-awn, carrionflower greenbriar, dwarf wild indigo, and plains cottonwood riparian woodland communities. Each of these communities is described in detail in Section 2.9.1.

2.10 References

AAI, 1998, Results of the Aquatic Monitoring Program in Big Dry Creek, Interim Report, Aquatics Associates Inc., Prepared for the Cities of Broomfield, Northglenn, and Westminster, Colorado.

AAI, 2003, Results of the Aquatic Monitoring Program in Streams at the Rocky Flats Site, 2001-2002, Aquatics Associates Inc., Prepared for U.S. DOE, Rocky Flats Field Office, Golden, Colorado.

AeroVironment, 1995, Rocky Flats Environmental Technology Site Historical Data Summary (AV-R-9308-200), AeroVironment, Inc., February.

Armstrong, D.M., M.E. Bakeman, A. Deans, C.A. Meaney, and T.R. Ryon, 1997, Report on Habitat Findings of the Preble's Meadow Jumping Mouse in Colorado, Boulder, Report to the U.S. Fish and Wildlife Service and Colorado Division of Wildlife.

Blatt, H., G. Middleton, and R. Murray, 1980, *Origin of Sedimentary Rocks*, Prentice Hall, Inc., Englewood Cliffs, New Jersey.

Brennan, M., 2003, Boulder County Parks and Open Space Department, Personal communication with Ron Beane, ERO Resources, April 16 (as referenced in the Rocky Flats National Wildlife Refuge Final Comprehensive Conservation Plan and Environmental Impact Statement, September 2004).

CDOW, 1992, Plains Sharp-Tailed Grouse Recovery Plan, Colorado Division of Wildlife.

CDOW, 2001, Colorado Vertebrate Ranking System (COVERS) database, Colorado Division of Wildlife, ftp:/www.NDIS.NREL.colostate.edu/.

CDOW, 2003, Grassland Species Conservation Plan, Colorado Division of Wildlife.

CDPHE, 2002, CDPHE Hazardous Materials and Waste Management Division, Corrective Action Guidance Document, May.

CH2M Hill, 1996, Final Construction Report for the Woman Creek Dam and Reservoir Project, Prepared by CH2M Hill, February.

Clippinger, N., 1989, Habitat Suitability Index Models: Black-Tailed Prairie Dog, Biological Report 82 (10.156): 1-21, U.S. Fish and Wildlife Research and Development, Washington, D.C.

CNHP, 1994, Natural Heritage Resources of the Rocky Flats Environmental Technology Site and Their Conservation, Phase 1: Rock Creek, Final Report, Colorado Natural Heritage Program, Colorado State University, Fort Collins, Colorado.

CNHP, 1995, Natural Heritage Resources of the Rocky Flats Environmental Technology Site and Their Conservation, Phase 2: The Buffer Zone, Final Report, Colorado Natural Heritage Program, Colorado State University, Fort Collins, Colorado.

DOE, 1995, Ecological Monitoring Program, 1995 Annual Report, Rocky Flats Field Office, Rocky Flats Environmental Technology Site, Golden, Colorado.

DOE, 1996, Final Phase I RFI/RI Report: Woman Creek Priority Drainage, Operable Unit 5, Volume 5, Appendix N, Ecological Risk Assessment for Woman Creek and Walnut Creek Watersheds at the Rocky Flats Environmental Technology Site, Rocky Flats Field Office, Rocky Flats Environmental Technology Site, Golden, Colorado.

DOE, 1997, Rocky Flats Cumulative Impacts Document, Rocky Flats Field Office, Rocky Flats Environmental Technology Site, Golden, Colorado.

DOE, 1998, Historic American Engineering Record (HAER) Survey No. CO-83, A-Z, AA-AI, Submitted to the HAER on June 1, 1998.

DOE, 1999, Vegetation Management Environmental Assessment, Rocky Flats Field Office, Rocky Flats Environmental Technology Site, Golden, Colorado.

DOE, 2000, Natural Resource Management Policy, Rocky Flats Environmental Technology Site, Golden, Colorado.

DOE, 2002, Final Work Plan for the Development of the Remedial Investigation and Feasibility Study Report, Rocky Flats Environmental Technology Site, Golden, Colorado, March 11.

DOE, 2004a, Environmental Assessment Comment Response and Finding of No Significant Impact, Pond and Land Configuration, DOE/EA – 1492, Rocky Flats Project Office, Golden, Colorado, October.

DOE, 2004b, Interim Measure/Interim Remedial Action for the Original Landfill (Including IHSS Group SW-2; IHSS 115, Original Landfill and IHSS 196, Filter Backwash Pond), Kaiser-Hill Company, L.L.C., Rocky Flats Environmental Technology Site, Golden, Colorado.

DOE, 2004c, Interim Measure/Interim Remedial Action and Closure Plan for the Present Landfill, Kaiser-Hill Company, L.L.C., Rocky Flats Environmental Technology Site, Golden, Colorado.

DOE, 2004d, Programmatic Biological Assessment for the Department of Energy Activities at the Rocky Flats Environmental Technology Site, Part II, Revision 7, DOE, Rocky Flats Project Office, Golden, Colorado, April.

DOE, 2005, Interim Measure/Interim Remedial Action for Groundwater at the Rocky Flats Environmental Technology Site, Golden, Colorado, June 21.

DOE/USFWS, 2001, Integrated Natural Resources Management Plan, Environmental Assessment and Finding of No Significant Impacts for Rock Creek Reserve, 2001-Closure, U.S. Department of Energy/U.S. Fish and Wildlife Service.

DRCOG, 2004, Summary Population and Household Forecasts, Denver Regional Council of Governments, Metro Vision Resource Center, Denver, Colorado. Available via the DRCOG website: http://www.drcog.org/MVRC/socio.html.

Ebasco, 1992, Baseline Biological Characterization of the Terrestrial and Aquatic Habitats at Rocky Flats Plant, Prepared for U.S. DOE, Ebasco Environmental Consultants Inc., Rocky Flats Field Office, Golden, Colorado.

EG&G, 1991, Geologic Characterization Report, EG&G Rocky Flats, Inc., Rocky Flats Plant, Golden, Colorado.

EG&G, 1993, Background Geochemical Characterization Report, EG&G Rocky Flats, Inc., Rocky Flats Plant, Golden, Colorado, September.

EG&G, 1995a, Geologic Characterization Report for the Rocky Flats Environmental Technology Site, Vol. 1, EG&G Rocky Flats, Inc., Rocky Flats Environmental Technology Site, Golden, Colorado, March.

EG&G, 1995b, Hydrogeologic Characterization Report for the Rocky Flats Environmental Technology Site, Volume II of the Sitewide Geoscience Characterization

Study, EG&G Rocky Flats, Inc., Rocky Flats Environmental Technology Site, Golden, Colorado, April.

EG&G, 1995c, Geochemical Characterization of Background Surface Soils: Background Soil Characterization Program, EG&G Rocky Flats, Inc., Rocky Flats Environmental Technology Site, Golden, Colorado, May.

EG&G, 1995d, Groundwater Geochemistry Report for the Rocky Flats Environmental Technology Site, Volume III of the Sitewide Geoscience Characterization Study, Golden, Colorado, January.

EPA, 1988, Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA, October.

ESCO, 1994, Report of Findings: Ute Ladies'-Tresses and Colorado Butterfly Weed Surveys, Rocky Flats Buffer Zone, Jefferson County, Colorado.

ESCO, 2002, Draft Report of Findings: Five-Year Study of the Ecology of Bluestem-Dominated Grasslands of the Rocky Flats Area, 1996-2001, Jefferson and Boulder Counties, Colorado.

Essington, K.D., S.M. Kettler, S.E. Simonson, C.A. Pague, J.S. Sanderson, P.M. Pined, and A.R. Ellingson, 1996, Natural Heritage Resources of the Rocky Flats Environmental Technology Site and Their Conservation, Phase II: The Buffer Zone, Colorado Natural Heritage Program, Fort Collins, Colorado.

Exponent, 1998, Final Report: Lower Walnut Creek Aquatic Sampling for the Rocky Flats Environmental Technology Site, Prepared by Exponent Environmental Group for Kaiser-Hill Company, L.L.C., Rocky Flats Environmental Technology Site, Golden Colorado.

Gershman, M., 1992, Comment letter (on the CCP) from Mark Gershman, City of Boulder Open Space to Clair Broun (CDOW) on the Draft Plains Sharp-Tailed Grouse Recovery Plan, January.

Haun, J.D. and H.C. Kent, 1965, "Geologic History of the Rocky Mountain Region," *Bull. of the American Association of Petroleum Geologists*, v 49, no. 11, p. 1781-1800.

Howard, T., 2003, District Wildlife Manager, Colorado Division of Wildlife, Personal communication with Ron Beane, ERO Resources Corporation, July 3.

Hurr, R.T., 1976, Hydrology of a Nuclear-Processing Plant Site, Rocky Flats, Jefferson County, Colorado, U.S. Geological Survey Open-File Report 76-268, 68 pp.

K-H, 1997a, Metadata report accompanying veg96b.shp GIS data showing land cover data derived from 1995 - 1996 field surveys, Kaiser-Hill Company, L.L.C., Rocky Flats Environmental Technology Site, Golden, Colorado.

K-H, 1997b, Terrestrial Vegetation Survey (1993-1995) for the Rocky Flats Environmental Technology Site, Prepared by PTI Environmental Services for Kaiser-Hill Company, L.L.C., Rocky Flats Environmental Technology Site, Golden, Colorado.

K-H, 1998, 1997 Annual Wildlife Survey Report for the Rocky Flats Environmental Technology Site, Kaiser-Hill Company, L.L.C., Rocky Flats Environmental Technology Site, Golden, Colorado.

K-H, 1999, 1998 Annual Wildlife Survey Report for the Rocky Flats Environmental Technology Site, Kaiser-Hill Company, L.L.C., Rocky Flats Environmental Technology Site, Golden, Colorado.

K-H, 2000a, 1999 Annual Wildlife Survey for the Rocky Flats Environmental Technology Site, Kaiser-Hill Company, L.L.C., Rocky Flats Environmental Technology Site, Golden, Colorado.

K-H, 2000b, Appendix B, 1999 Study of the Preble's Meadow Jumping Mouse at the Rocky Flats Environmental Technology Site, in 1999 Annual Wildlife Survey for the Rocky Flats Environmental Technology Site, Kaiser-Hill Company, L.L.C., Rocky Flats Environmental Technology Site, Golden, Colorado.

K-H, 2001, 2000 Annual Wildlife Survey for the Rocky Flats Environmental Technology Site, Kaiser-Hill Company, L.L.C., Rocky Flats Environmental Technology Site, Golden, Colorado.

K-H, 2002a, Site-Wide Water Balance Modeling Report for the Rocky Flats Environmental Technology Site, Kaiser-Hill Company, L.L.C., Rocky Flats Environmental Technology Site, Golden, Colorado.

K-H, 2002b, Final 2001 Annual Rocky Flats Cleanup Agreement Groundwater Monitoring Report for the Rocky Flats Environmental Technology Site, Kaiser-Hill Company, L.L.C., Rocky Flats Environmental Technology Site, Golden, Colorado.

K-H, 2002c, 2001 Annual Vegetation Report for the Rocky Flats Environmental Technology Site, Kaiser-Hill Company, L.L.C., Rocky Flats Environmental Technology Site, Golden, Colorado.

K-H, 2002d, 2002 Annual Vegetation Management Plan for the Rocky Flats Environmental Technology Site, Kaiser-Hill Company, L.L.C., Rocky Flats Environmental Technology Site, Golden, Colorado.

K-H, 2002e, 2001 Annual Wildlife Survey Report for the Rocky Flats Environmental Technology Site, Kaiser-Hill Company, L.L.C., Rocky Flats Environmental Technology Site, Golden, Colorado.

K-H, 2004a, Land Configuration Design Basis Project, Industrial Area Grading and Drainage Plans, Engineered Channels, Draft Issued for Construction Submittal, Kaiser-

Hill Company, L.L.C., Rocky Flats Environmental Technology Site, Golden, Colorado, December 22.

K-H, 2004b, Final Fate and Transport Modeling of Volatile Organic Compounds at the Rocky Flats Environmental Technology Site, Golden, Colorado, April.

K-H, 2005a, Summary of Integrated Hydrologic Flow and Fate and Transport Modeling Conducted at the Rocky Flats Environmental Technology Site, Golden, Colorado, September.

K-H, 2005b, 2004 Annual Ecology Report for the Rocky Flats Environmental Technology Site, prepared for Rocky Flats Field Office, Rocky Flats Environmental Technology Site, Golden, Colorado, June.

Kettler, S.M., S.E. Simonson, C.A. Pague, and A.R. Ellingson, 1994, Significant Natural Heritage Resources of the Rocky Flats Environmental Technology Site and Their Conservation, Phase I: The Rock Creek Drainage, Colorado Natural Heritage Program, Fort Collins, Colorado.

Kuford, C.C., 1958, Prairie Dogs, Whitefaces and Blue Grama, Wildlife Monograph 1-78.

Lane, E., 2004, State Weed Coordinator, Colorado Department of Agriculture, Information provided in comments to Draft CCP/EIS, April 26.

Leroy, L.W. and R.J. Weimer, 1971, Geology of the Interstate 70 Road Cut, Jefferson County Colorado, Colorado School of Mines Professional Contribution No. 7.

Nelson, J., 2003, Senior Ecologist, Kaiser-Hill Ecology Group, Rocky Flats Environmental Technology Site, Personal communication with Bill Mangle, ERO Resources, January 14.

Paine, D., 1980, “Plutonium in Rocky Flats Freshwater Systems,” in *Transuranic Elements in the Environment; A Summary of Environmental Research on Transuranium Radionuclides* funded by the U.S. Department of Energy through Calendar Year 1979, W.C. Hanson, ed., DOE/TIC-22800, Technical Information Center, U.S. Department of Energy.

Power, M.E., D. Tilman, J.A. Estes, B.A. Menge, W.T. Bond, L.S. Mills, G. Daily, J.C. Castilla, J. Lutchonco, and R.T. Paine, 1996, “Challenges in the Quest for Keystone Species,” *BioScience* 46:609-620.

Price, A.B. and A.E. Amen, 1983, Soil Survey of the Golden Area, Colorado - Parts of Denver, Douglas, Jefferson, and Park Counties: U.S. Department of Agriculture, Soil Conservation Service.

PTI, 1997a, 1997 Annual Vegetation Report for the Rocky Flats Environmental Technology Site, Prepared by PTI Environmental Services for Kaiser-Hill Company, L.L.C., Rocky Flats Environmental Technology Site, Golden, Colorado.

PTI, 1997b, Ecological Resource Management Plan for the Rocky Flats Environmental Technology Site, PTI Environmental Services, Prepared for Kaiser-Hill Company, L.L.C., Rocky Flats Environmental Technology Site, Golden, Colorado.

REI, 1994, Seismic Hazard Study, Systemic Evaluation Program for EG&G Rocky Flats Plant, Golden, Colorado, by Risk Engineering, Inc., 9217-COO-204, Rev 0, September 29.

RMRS, 1996, White Paper: Analysis of Vertical Contaminant Migration Potential, Rocky Mountain Remediation Services, L.L.C., Rocky Flats Environmental Technology Site, Golden, Colorado, August.

RMRS/DOE, 1995, Rocky Flats RFI/RI for OU3 (General Report), Section 3.3 (Draft), Rocky Flats Environmental Technology Site, Golden, Colorado, August.

Rockwell, 1988, Resource Conservation and Recovery Act Post-Closure Care Permit, Vol. 6, App. 6 Section 5 and Section 3, Rockwell International, October.

Rosenlund, B., 2003, Draft paper on native fish restoration, U.S Fish and Wildlife Service.

Ryon, T.R., 2001, "Summer nests of Preble's meadow jumping mouse," *The Southwestern Naturalist*, Vol. 46 (3).

SAIC, 1996, Final Draft Cultural Resource Management Plan: Rocky Flats Environmental Technology Site, Prepared by Science Applications International Corporation for the DOE Rocky Flats Field Office, Golden, Colorado, March 29.

Smith R.E., 1967, Natural History of the Prairie Dog in Kansas, University of Kansas Museum of Natural History, Misc. Publication No. 49.

Spencer, 1961, Bedrock Geology of the Louisville Quadrangle, Colorado, U.S. Geological Survey, Geological Quadrangle Map GQ-151.

Stone, E., 2004, Biologist, U.S. Fish and Wildlife Service, Personal communication with Bill Mangle, ERO Resources, January 5 (as referenced in the Rocky Flats National Wildlife Refuge Final Comprehensive Conservation Plan and Environmental Impact Statement, September 2004).

UDFCD, 2001, Urban Storm Drainage Criteria Manual, Volume 1, Urban Drainage and Flood Control District, Denver, Colorado, June.

USACE, 1994, Rocky Flats Plant Wetland Mapping and Resource Study (prepared for U.S. Department of Energy), U.S. Army Corps of Engineers, Omaha District, December.

USFWS, 2002, Candidate Conservation Program, U.S. Fish and Wildlife Service, http://endangered.fws.gov/candidates/index.html.

USFWS, 2003, Endangered and Threatened Wildlife and Plants; Designation of Critical Habitat for the Preble's Meadow Jumping Mouse *(Zapus hudsonius preblei)*, U.S. Fish and Wildlife Service, Federal Register, 68: 37276-37332, June 23.

USFWS, 2004a, Rocky Flats National Wildlife Refuge, Final Comprehensive Conservation Plan and Environmental Impact Statement, U.S. Fish and Wildlife Service, September.

USFWS, 2004b, Endangered and Threatened Wildlife and Plants; Finding for the Resubmitted Petition to List the Black-Tailed Prairie Dog as Threatened, U.S. Fish and Wildlife Service, Federal Register, 69: 51217-51226.

USFWS, 2004c, Programmatic Biological Assessment for Department of Energy Activities at the Rocky Flats Environmental Technology Site, Part I Appendix A Preble's Meadow Jumping Mouse Protection Plan for the Rocky Flats Environmental Technology Site (December 2003), U.S. Department of Energy, Rocky Flats Field Office, Golden, Colorado, January.

USFWS, 2004d, Endangered and Threatened Wildlife and Plants; 90-Day Finding for a Petition to Delist the Preble's Meadow Jumping Mouse in Colorado and Wyoming and Initiation of a 5-Year Review, U.S. Fish and Wildlife Service, Federal Register, 69: 16944-16946, March 31.

USGS, 1996, Surficial Geologic Map of the Rocky Flats Environmental Technology Site and Vicinity, Jefferson and Boulder Counties, Colorado, U.S. Geological Survey.

USGS, 2002, USGS Earthquakes Hazard Program, National Seismic Mapping Project, http://eqhazmaps.usgs.gov.

Wedermyer, M., 2003, District Wildlife Manager, Colorado Division of Wildlife, Personal communication with Ron Beane, ERO Resources Corporation, July 1.

Weimer, R.J., 1973, "A guide to Uppermost Cretaceous stratigraphy, central Front Range, Colorado: Deltaic sedimentation, growth faulting and early Laramide crustal movement, " *The Rocky Mountain Geologist*, Rocky Mountain Association of Geologists, v. 10, p. 53-97.

Whicker, A.D. and J.K. Detling, 1988, "Ecological Consequences of Prairie Dog Disturbances," *BioScience*, 38:778- 785.

Witmer, G.W., K.C. VerCauteren, K.M. Manci, and D.M. Dees, 2002, Urban-suburban prairie dog management opportunities and challenges, Proceedings of 19th Vertebrate Pest Conference 19:439-444.

WWE, 2003, Supplemental Biological Data from Big Dry Creek, Prepared by Wright Water Engineers, Inc. for Kaiser-Hill Company, L.L.C., Rocky Flats Environmental Technology Site, Golden, Colorado.

Table 2.1
SUMMARY OF GEOTECHNICAL PROPERTIES OF SOIL AND OVERBURDEN

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Preble's Meadow Jumping Mouse (PMJM) Habitat

TABLES

Table 2.1
Summary of Geotechnical Properties of Soil and Overburden

Soil Name	Sample Depth (inches)	Unified Soil Classification	Percentage Passing Sieve Number				Liquid Limit	Plasticity Index	Permeability (inches/hr)	Available Water Capacity (inches/inch)
			4	10	40	200				
Flatirons	0 – 13	GM, SM	40 – 80	35 – 70	20 – 45	10 – 30	15 – 25	0 – 5	2.0 – 6.0	0.07 – 0.10
	13 – 47	GC	40 – 60	35 – 55	30 – 50	25 – 40	35 – 60	20 – 50	0.06 – 0.2	0.08 – 0.10
	47 – 60	GC	40 – 60	35 – 55	30 – 50	15 – 30	25 – 35	10 – 20	0.6 – 2.0	0.08 – 0.10
Nederland	0 – 10	SM-SC	70 – 90	70 – 85	40 – 55	25 – 35	20 – 30	5 – 10	2.0 – 6.0	0.10 – 0.12
	10 – 62	SC	70 – 90	70 – 90	40 – 65	25 – 50	30 – 40	10 – 20	0.6 – 2.0	0.08 – 0.12
	62 – 70	SM-SC, SC	65 – 80	60 – 80	30 – 50	20 – 30	20 – 35	5 – 15	---	---
Denver	0 – 6	CL	95 – 100	90 – 100	75 – 100	70 – 90	30 – 50	10 – 25	0.2 – 0.6	0.16 – 0.20
	6 – 29	CH-CL	95 – 100	95 – 100	90 – 100	85 – 100	40 – 75	20 – 45	0.06 – 0.2	0.14 – 0.18
	29 – 60	CL, CH	95 – 100	90 – 100	80 – 100	75 – 95	35 – 60	15 – 30	0.06 – 0.6	0.014 – 0.18
Kutch	0 – 3	CL	95 – 100	90 – 100	90 – 100	70 – 80	30 – 50	15 – 30	0.2 – 0.6	0.15 – 0.20
	3 – 26	CH, CL	95 – 100	90 – 100	90 – 100	75 – 95	45 – 60	20 – 35	0.06 – 0.2	0.18 – 0.20
Midway	0 – 3	CL	75 – 100	75 – 100	70 – 100	70 – 95	30 – 40	10 – 20	0.2 – 0.6	0.14 – 0.18
	3 – 14	CL, CH	95 – 100	95 – 100	90 – 100	70 – 95	35 – 60	20 – 35	0.06 – 0.2	0.14 – 0.18
Haverson	0 – 6	ML	95 – 100	90 – 100	85 – 100	55 – 70	25 – 35	0 – 10	0.6 – 2.0	0.14 – 0.18
	6 – 46	CL, CL-ML	95 – 100	85 – 100	70 – 95	50 – 70	25 – 40	5 – 15	0.2 – 0.6	0.14 – 0.18
	46 – 60	GM, SM	35 – 55	30 – 50	20 – 40	5 – 15	---	0	0.2 – 0.6	0.04 – 0.06

Source: Price and Amen (1983)

GM = Silty gravels, gravel-sand-silt mixtures

SM = Silty sands, sand-silt mixtures

GC = Clayey gravels, gravel-sand-clay mixtures

SC = Clayey sands, sand-clay mixtures

CL = Inorganic clays of low to medium plasticity, gravelly/sandy/silty/lean clays

CH = Inorganic clays or high plasticity, fat clays

ML = Inorganic silts, very fine sands, rock four, silty or clayey fine sands

Table 2.2
Flow Data at Select Gaging Stations, Site Configuration During Accelerated Actions

Drainage	Tributary	Gaging Station	Mean Annual Discharge Volume (ac-ft)	Dates of Record	Peak Flow Rate (cfs) (15-min record)	Date of Peak Flow
Rock Creek	-	GS04	234.9	10/1/96-7/31/05	35.4	3/26/03
Walnut Creek	McKay Ditch	GS35	69.3	10/1/97-7/31/05	23.6	3/26/03
	No Name Gulch	GS33	16.6	10/1/97-7/31/05	6.8	5/1/99
	North Walnut Creek	SW093	145.3	10/1/96-7/31/05	134.9	7/14/01
	South Walnut Creek	GS10	100.5	10/1/96-7/31/05	112.6	8/27/00
	Entire Watershed	GS03	433.9	10/1/96-7/31/05	56.5	3/26/03
Woman Creek	SID	SW027	21.6	10/1/96-7/31/05	10.2	8/27/00
	N. Woman Creek	GS05	108.4	10/1/96-7/31/05	24.7	4/4/98
	Owl Branch	GS06	21.0	10/1/96-6/6/05	12.1	4/27/97
	Antelope Springs	GS16	93.4	10/1/96-7/31/05	8.6	4/4/98
	Entire Watershed	GS01	271.9	10/1/96-7/31/05	79.5	4/30/99

Table 2.3
Retention Ponds Characteristics

Drainage	Pond	Capacity (ac-ft)	Dam Characteristics	Inflow From:	Outflow To:	Function	Pond Operating Protocol
North Walnut Creek	A-1	4.3	- Earthen dam - with riprap spillway - Not keyed into firm foundation rock - No toe/interior drain	North Walnut Creek	Pond A-2	Sustain wetlands, provide additional non-routine storage capacity	Isolated pond offline from routine flow routing
	A-2	18.4	- Earthen dam - with riprap spillway - Keyed into firm foundation rock -Toe/interior drain	North Walnut Bypass or Pond A-1	Pond A-3	Sustain wetlands, provide additional non-routine storage capacity	Isolated pond offline from routine flow routing
	A-3	37.9	- Earthen dam - Keyed into firm foundation rock -Toe/interior drain - Outlet works	North Walnut Bypass or Pond A-2	Pond A-4	Sustain wetlands, stormflow detention and storage, and settling of suspended solids	Batch-release (released through outlet works when pool level reaches approx. 50 percent of capacity)
	A-4	98.6	- Earthen dam - Keyed into firm foundation rock - No toe/interior drain - Outlet works with standpipe inlet	Pond A-3	North Walnut Creek	Sustain wetlands, stormflow detention and storage, and settling of suspended solids	Batch-release (sampled when pool level reaches approx. 40 percent of capacity, then released through outlet works)
South Walnut Creek	B-1	2.6	- Earthen dam - with riprap spillway - Unknown if keyed into bedrock - Toe/interior drain	South Walnut Creek	Pond B-2	Sustain wetlands, provide additional non-routine storage capacity	Isolated pond offline from routine flow routing
	B-2	4.5	- Earthen dam - with riprap spillway - Unknown if keyed into bedrock - Toe/interior drain	Pond B-1	Pond B-3	Sustain wetlands, provide additional non-routine storage capacity	Isolated pond offline from routine flow routing

Table 2.3
Retention Ponds Characteristics

Drainage	Pond	Capacity (ac-ft)	Dam Characteristics	Inflow From:	Outflow To:	Function	Pond Operating Protocol
	B-3	2.9	- Earthen dam - with riprap spillway - Unknown if keyed into bedrock - Toe/interior drain - Outlet works	Pond B-2	Pond B-4	Sustain wetlands, provide additional non-routine storage capacity	Flow-through (outlet works open) but isolated from routine flow routing
	B-4	0.6	- Earthen dam - with concrete spillway - Unknown if keyed into bedrock - Toe/interior drain	South Walnut Bypass <u>or</u> Pond B-3	Pond B-5	Sustain wetlands, provide minor flow attenuation, and settling of suspended solids	Flow-through (South Walnut Creek flows through Pond B-4 and into Pond B-5)
	B-5	71.0	- Earthen dam - Keyed into bedrock - Toe/interior drain - Outlet works with standpipe inlet	Pond B-4	South Walnut Creek	Sustain wetlands, stormflow detention and storage, and settling of suspended solids	Batch-release (sampled when pool level reaches approx. 50 percent of capacity, then released through outlet works)
Walnut Creek	Flume Pond	0.5 (est.)	- Earthen dam - Unknown if keyed into bedrock - No outlet works	Walnut Creek	Walnut Creek	Provide minor flow attenuation and settling of suspended solids	Flow-through (Walnut Creek flows through the Flume Pond)
Woman Creek	C-1	1.8	- Earthen dam - Notched with stoplog outlet structure - Unknown if keyed into bedrock - Toe/interior drain - No outlet works	Woman Creek	Woman Creek	Sustain wetlands, provide minor flow attenuation, and settling of suspended solids	Flow-through (Woman Creek flows through Pond C-1)
	C-2	69.6	- Earthen dam - Keyed into bedrock - Toe/interior drain - Outlet works	SID	Woman Creek	Sustain wetlands, stormflow detention and storage, and settling of suspended solids	Batch-release (sampled when pool level reaches approx. 50 percent of capacity, then released through outlet works)
No Name Gulch	East Land-fill Pond	26.8	- Earthen dam - Unknown if keyed into bedrock - Toe/interior drain - Outlet works	Former Present Landfill area watershed	No Name Gulch	Sustain wetlands, provide localized stormflow storage, and settling of suspended solids	Flow-through

Table 2.4
Surface Water Discharge Volumes - During and After Accelerated Actions

			During Accelerated Actions[a] (Measured Discharge)		After Accelerated Actions[b] (Model-Predicted Discharge)		
Drainage	**Tributary**	**Gaging Station**	**Mean Annual Discharge Volume (ac-ft)**	**Dates of Record**	**Model Climate[c]**	**Predicted Annual Discharge Volume (ac-ft)[d]**	**Percent of Historic Mean Discharge Volume[d]**
Walnut Creek	North Walnut Creek	SW093	145.3	10/1/96-7/31/05	Typical[c]	51.4	35%
					Wet year[c]	76.9	53%
					Dry year[c]	44.9	31%
	South Walnut Creek	GS10	100.5	10/1/96-7/31/05	Typical[c]	11.6	12%
					Wet year[c]	17.2	17%
					Dry year[c]	10.5	10%
	Entire Watershed	GS03	433.9	10/1/96-7/31/05	Typical[c]	55.9	13%
					Wet year[c]	124.8	29%
					Dry year[c]	49.5	11%
Woman Creek	S. Interceptor Ditch	SW027	21.6	10/1/96-7/31/05	Typical[c]	1.6	7%
					Wet year[c]	3.2	15%
					Dry year[c]	1.3	6%
	Entire Watershed	GS01	271.9	10/1/96-7/31/05	Typical[c]	130.1	48%
					Wet year[c]	186.6	69%
					Dry year[c]	115.8	43%

Note: The dash in the discharge volume column indicates no estimate.

[a]Mean annual discharge during accelerated actions based on measured flow data.

[b]Mean annual discharge after accelerated actions based on MIKE SHE model simulations, using best available site topography information available at the time modeling was conducted in September 2005.

[c]Model climate: (1) Typical = Water Year 2000 precipitation depth = 13.8 inches (compared to RFETS annual depth of 14.8 inches), (2) Wet year simulation based on 19.4 inches annual precipitation depth (Ft. Collins mean depth plus 1 standard deviation), and (3) Dry year simulation based on 11 inches annual precipitation depth (Ft. Collins mean depth minus 1 standard deviation).

[d]Model-predicted values are subject to uncertainty. Model results are best utilized to evaluate relative changes observed in the RFETS hydrology resulting from changing watershed and/or climate conditions. Use of model predictions as absolute values for future changing conditions is not advised.

Table 2.5
Summary of Monthly Precipitation Data

Month	Precipitation Water Equivalent (inches)		
	Monthly Mean	Monthly Maximum (Year)	Daily Maximum (Date)
January	0.40	1.12 (1974)	0.50 (1/12/72)
February	0.52	1.28 (1971)	0.70 (2/20/71)
March	1.18	4.70 (1970)	1.06 (3/30/70)
April	1.77	4.73 (1973)	2.30 (4/13/67)
May	2.65	9.70 (1969)	3.40 (5/6/69)
June	1.56	4.79 (1969)	2.94 (6/27/87)
July	1.47	5.10 (1965)	1.57 (7/16/00)
August	1.42	3.69 (1967)	2.10 (8/30/67)
September	1.48	4.53 (1976)	1.81 (9/26/76)
October	0.90	4.83 (1969)	1.83 (10/4/84)
November	0.79	2.00 (1972)	0.75 (11/1/72)
December	0.40	1.45 (1973)	0.50 (12/23/73)

Sources: AeroVironment (1995) (1964 through 1977 and 1984 through 1993) and K-H precipitation data (1994 through 2004)

Table 2.6
Summary of Monthly Temperature Data

Month	Average Temperatures (°F)			Extreme Temperatures (°F)	
	Monthly Average Temperature	Highest Monthly Average Temperature (Year)	Lowest Monthly Average Temperature (Year)	Maximum Temperature (Date)	Minimum Temperature (Date)
January	32.9	40.2 (1986)	19.4 (1984)	69.7 (01/02/97)	-12.4 (01/12/97)
February	33.9	40.7 (1999)	22.9 (1964)	71.0 (02/28/72)	-9.3 (02/24/03)
March	38.7	46.5 (1972)	28.0 (1965)	82.0 (03/26/71)	-5.0 (03/25/65)
April	45.9	52.0 (1992)	38.4 (1973)	80.7 (04/30/92)	5.0 (04/09/73)
May	55.4	61.3 (1974)	48.0 (1969)	92.7 (05/29/00)	26.0 (05/01/70)
June	64.4	71.8 (1971)	58.9 (1969)	99.0 (06/23/71)	31.5 (06/05/98)
July	71.1	76.6 (2003)	66.1 (1992)	102.0 (07/12/71)	37.6 (07/17/75)
August	69.0	72.6 (1970)	64.6 (2004)	97.0 (08/08/69)	43.0 (08/28/04)
September	60.8	66.6 (1998)	53.2 (1965)	91.0 (09/10/74)	24.0 (09/19/71)
October	50.8	57.1 (1965)	38.8 (1969)	82.1 (10/16/91)	4.0 (10/14/69)
November	39.9	51.0 (1965)	30.7 (2000)	72.0 (11/25/70)	-3.3 (11/24/93)
December	33.7	39.7 (1976)	25.8 (1990)	72.0 (12/04/65)	-23.6 (12/21/90)
Extremes		**Highest Annual Average Temperature (°F)**	**Lowest Annual Average Temperature (°F)**	**Maximum Temperature (°F)**	**Minimum Temperature (°F)**
		52.5 (1988)	31.3 (1985)	102 (07/12/71)	-23.6 (12/21/90)

Sources: AeroVironment (1995) (1964 through 1977 and 1984 through 1993) and K-H AIR database (1997 through 2004)

Table 2.7
Summary of Wind Speed Data

Month	Average Wind Speed (mph)[a]	Average Peak Wind Speed (mph)[b]
January	11.9	50.3
February	11.0	62.3
March	10.4	65.6
April	10.2	61.8
May	9.1	54.3
June	8.6	55.0
July	8.3	46.7
August	8.0	44.0
September	8.1	50.0
October	8.4	52.8
November	9.9	67.8
December	10.7	70.9
Annual Average	**9.5**	

Sources: AeroVironment (1995) (1964 through 1977 and 1984 through 1993) and K-H AIR database (1997 through 2004)

[a]Based on data collected from 1964 through 1977, 1984 through 1993, and 1997 through 2004
[b]Based on data collected from 1953 through 1977, 1984 through 1993, and 1997 through 2004

Table 2.8
Population and Households in Denver Metropolitan Area Counties

County	2000 Population[a] (Households)	2004 Population[b] (Households)
Adams	348,618 (127,299)	398,165 (148,889)
Arapahoe	487,967 (196,835)	524,414 (217,220)
Boulder	274,234 (113,464)	290,588 (121,483)
Broomfield	38,272 (14,322)	44,951 (17,268)
Clear Creek	9,322 (5,128)	9,607 (5,344)
Denver	554,636 (251,435)	572,862 (265,428)
Douglas	175,766 (63,333)	234,193 (85,966)
Gilpin	4,757 (2,929)	5,032 (3,213)
Jefferson	525,507 (211,916)	531,654 (220,619)
Region	2,419,079 (986,661)	2,611,466 (1,085,430)

Source: DRCOG (2004)

[a]Based on U.S. Census 2000
[b]Based on DRCOG estimate for January 1, 2004

Table 2.9
List of Private Easement Holders

Reference No. on Figure 2.4	Easement/License Holder	Purpose	Recording Information (Jefferson County) Book/Page or Reception Numbers
1, 2, 3, 4	Industrial Gas Services, Inc.	Natural gas pipeline	(1)2530/987; (2)2531/801; (3)2534/289; (4)2521/438
5, 7, 8, 9	Colorado-Wyoming Gas Co.	Oil and gas pipelines	(5)1570/443; (7)771/9120; (8)1570/430; (9)1570/437
6	Western Slope Gas Co.	Gas pipeline	(6)Reception No.103793
10	No easement documentation	Believed to be occupied by a gas pipeline	No recording information available
11, 12, 13, 14, 15, 16, 17, 18, 20	Public Service Co. of Colorado	Electric power and transmission lines	(11)2211/438 and 2866/666; (12)1794/504 (warranty deed); (13)No recording information available; (14)1838/14; (15)1766/542; (16)1838/12; (17)750/379 and 857/553; (18)No easement documents created; (20)No recording information available
19	Public Service Co. of Colorado	Electric transmission line and access road	(19)No recording information available
21	Union Rural Electric Ass'n, Inc.	Electric transmission line and access driveways	(21)No recording information available
22	Perry McKay	Ingress/egress	(22)Reception No.87067103
23	N/A (License to DOE from Denver and Rio Grande Western Railroad for telecommunications cable)	N/A	(23)No recording information available
24	N/A (License to DOE from Denver Water Board for bridge and road construction over ditch)	N/A	(24)No recording information available
25, 26	Mountain States Tel. & Tel.	Underground telecommunications cable	(25)1804/238; (26)No recording information available
27	City of Broomfield	McKay bypass pipeline for water conveyance	(27)No recording information available
28	N/A (DOE-owned telecommunications line)	Telecommunications cable	(28)N/A
29	No easement documentation	Electric power line providing power to single residence on east side of Indiana Street, traffic lights at SH128/Indiana, SH128/McCaslin	(29) No recording information available
30	N/A (DOE-owned power line)	N/A	(30)N/A
31	N/A (DOE-owned right-of-way for water pipeline and railroad spur)	N/A	(31)N/A

Table 2.10
Vegetation Communities

Vegetation Community	Acres
Grasslands	
Xeric Tallgrass Grassland	1,568
Mesic Mixed Grassland	2,199
Xeric Needle-and-Thread Grassland	187
Reclaimed Mixed Grassland	640
Short Grassland	10
Shrublands	
Tall Upland Shrubland	34
Riparian Shrubland	41
Other Shrubland	70
Woodlands	
Riparian Woodland	28
Ponderosa Pine Woodland	9
Wetlands	
Tall Marsh Wetland	31
Short Marsh Wetland	121
Wet Meadow	254
Open Water/Mudflats	51
Other	
Disturbed and Developed Areas	997
Total	**6,240**

Source: Rocky Flats National Wildlife Refuge Final CCP and EIS (USFWS 2004a)

Table 2.11
Major Noxious Weeds Inventory

Weed	High Density (acres)	Medium Density (acres)	Low Density (acres)	Scattered Density (acres)	Total Infested Area (acres)
Mullein	147	183	627	500	1357
Diffuse knapweed	381	525	674	377	1957
Musk thistle	9	84	430	346	869

Source: 2001 Annual Vegetation Report for the Rocky Flats Environmental Technology Site (K-H 2002c)

Table 2.12
Grassland Fires Documented at RFETS Since 1993[a]

Date	Wildfire or Controlled Burn?	Location	Estimated Burn Area (acres)
1993	Wildfire	South BZ, approximately 0.2 mile southeast of Pond C-1	0.14
1994	Wildfire	North BZ, adjacent to Highway 128, directly north of IA	70
1996 (Labor Day)	Wildfire	Southwest BZ, contained by BZ roads	104
2000 (April 6)	Controlled burn	Southwest BZ, contained by BZ roads (partial overlap with 1996 Labor Day fire area)	48
2000 (July 10)	Wildfire	Southeast BZ, approximately 0.3 mile south of east access gate on Indiana Street	8
2000 (September 10)	Wildfire	Northwest BZ, north of Pond A-4 and approximately 0.2 mile south of Highway 128	0.52
2002 (February 24)	Wildfire	Northeast BZ, adjacent to Highway 128, north of Landfill Pond	26
2002 (February 24)	Wildfire	Northeast BZ, between Highway 128 and Lindsay Pond 1	1

Source: Rocky Flats National Wildlife Refuge Final CCP and EIS (USFWS 2004a)

[a] In 2005, two incidences involving fires of erosion control material occurred at the Original Landfill. The first incident involved less than 1 acre and the second involved less than 10 ft^2 of erosion control material.

Table 2.13
Summary of PMJM Radio Telemetry Studies at Rocky Flats (1998-2000)

Drainage /Study Year	Density Estimate[a] (Population /linear km of stream)	Stream Length[a]	Population Estimate[a]	Maximum Distance Perpendicular to Stream	Average Distance Moved in 24 Hours	Maximum Distance Moved in 24 Hours	Average Linear Reach	Maximum Linear Reach	Average Home Range
Rock Creek 1998[b]	2.7	12.8 km	35	245 m[c]	142 m[c]	1,025 m[c]	715 m[c]	1610 m[c]	4.3 ha[d]
Walnut Creek 1999[e]	3.6	5.5 km	20	68 m[d]	57 m/55 m[d, f]	485 m[d]	320 m/282 m[d, f]	597 m[d]	1.5 ha[d]
Woman Creek 2000[g]	6.5	3.4 km	22	73 m[a]	68 m[a]	443 m[a]	629 m[a]	1397 m[a]	1.9-5.9 ha[a, h]

[a] Source: K-H 2001

[b] Rock Creek 1998; Session 1: June 17-July 2; Session 2: August 24-September 11

[c] Source: K-H 1999

[d] Source: K-H 2000b

[e] Walnut Creek 1999; Session 1: May 20-June 18; Session 2: August 23-September 16

[f] Session 1/Session 2

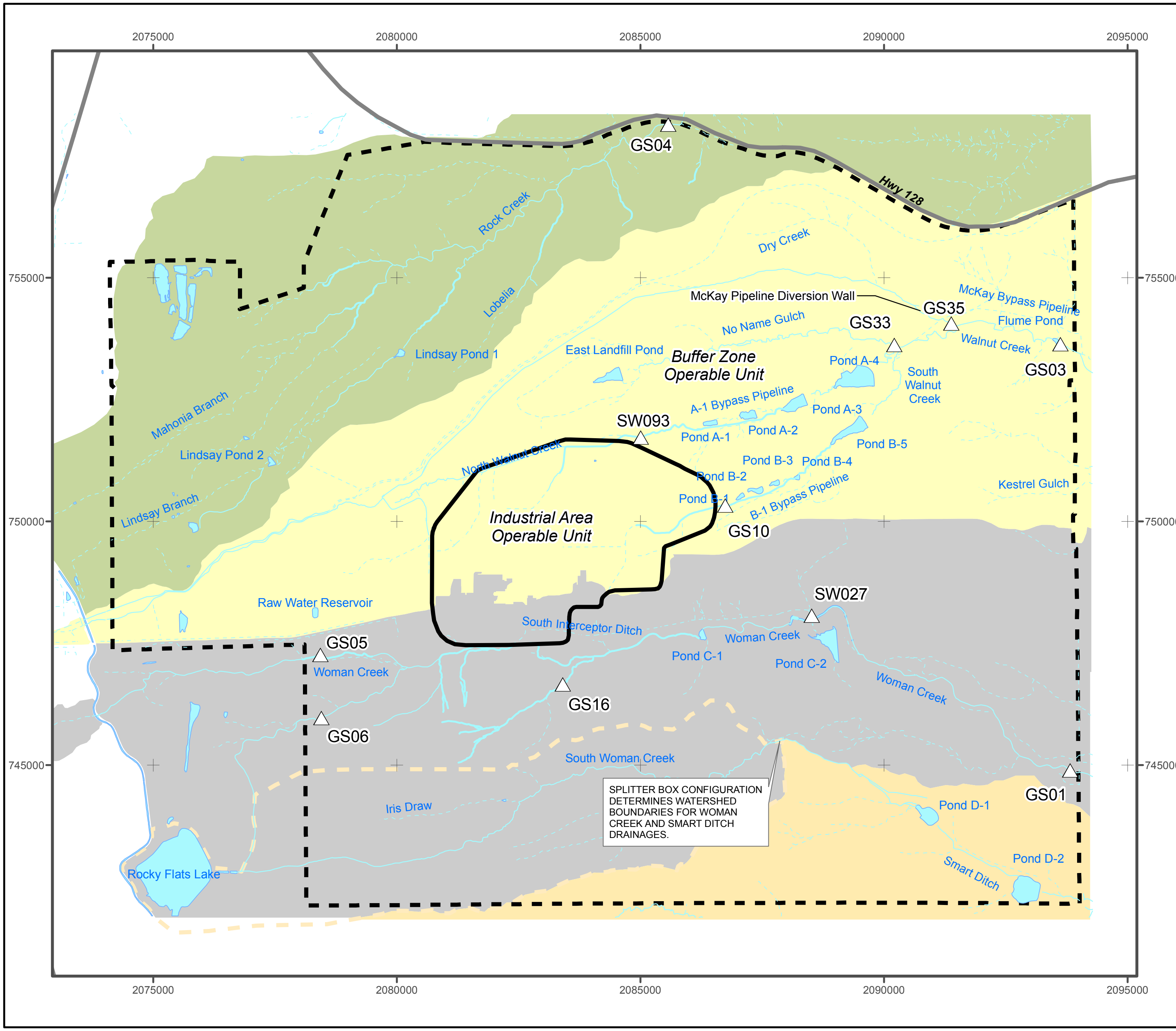
[g] Woman Creek 2000; Session 1: May 30-June 20; Session 2: August 21-September 14

[h] Only a range was given

FIGURES

Figure 2.1

Surface Water Features



KEY

- Gaging station
- Lower Smart Ditch drainage basin
- Rock Creek drainage basin
- Walnut Creek drainage basin
- Woman Creek drainage basin
- Regional road

Standard Map Features

- IA OU boundary
- Pond
- Site boundary
- Perennial stream
- Intermittent stream
- Ephemeral stream

N W E S

0 1,500 3,000 Feet

Scale 1:36,000

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD 27

U.S. Department of Energy
Rocky Flats Environmental
Technology Site

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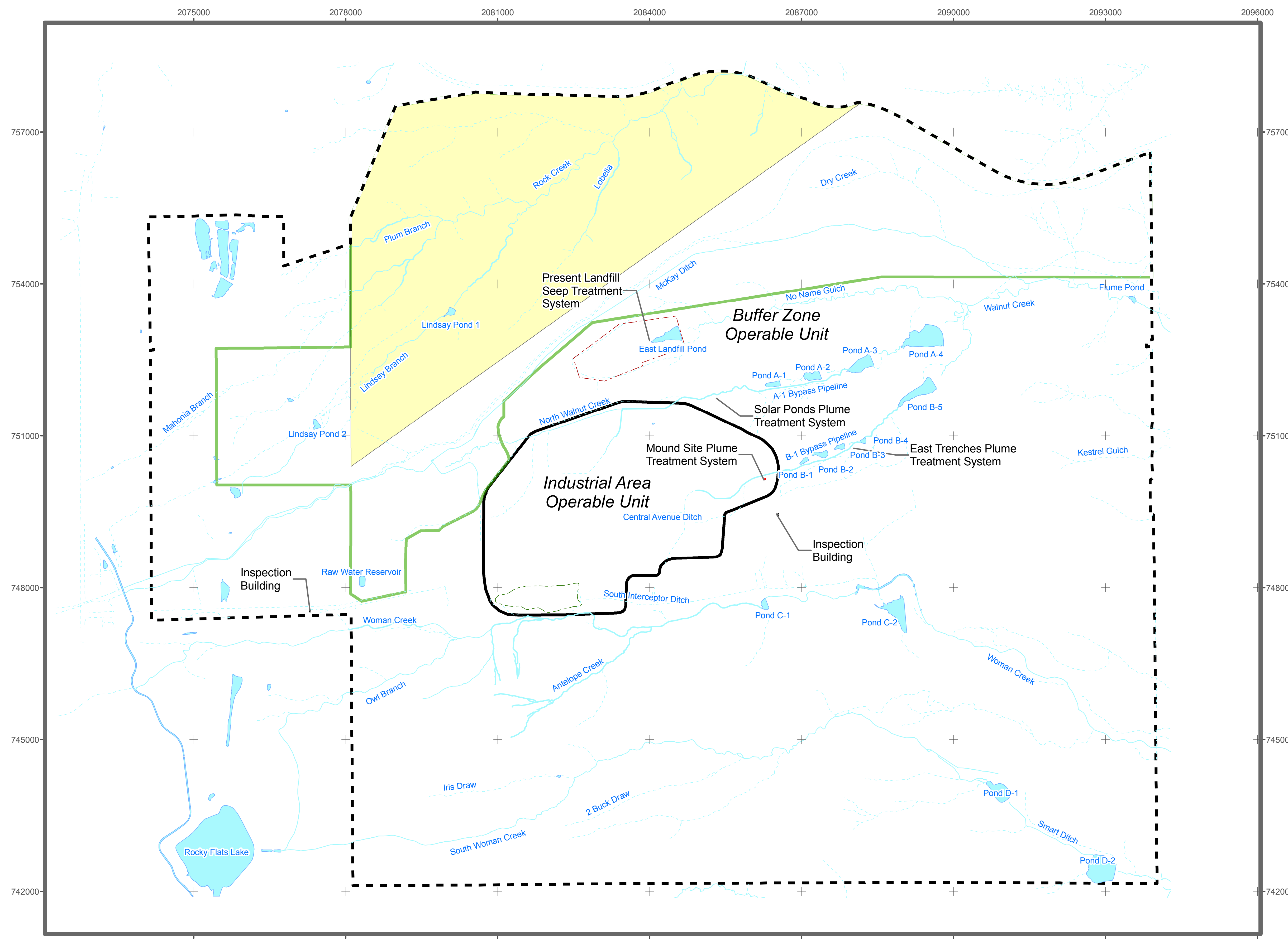
Figure 2.2

Surface Features and Treatment Systems After Accelerated Actions



KEY

- Original Landfill IHSS boundary
- Present Landfill IHSS boundary
- Existing Rock Creek Reserve (852 acres)
- Proposed Rock Creek Reserve (1,789 acres)

Note:
The Reserve boundary is an estimate only and does not represent a legal boundary.

Standard Map Features

- IA OU boundary
- Pond
- Site boundary
- Perennial stream
- Intermittent stream
- Ephemeral stream

N
W E
S

0 1,000 2,000 Feet

Scale 1:24,000

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD 27

U.S. Department of Energy
Rocky Flats Environmental
Technology Site

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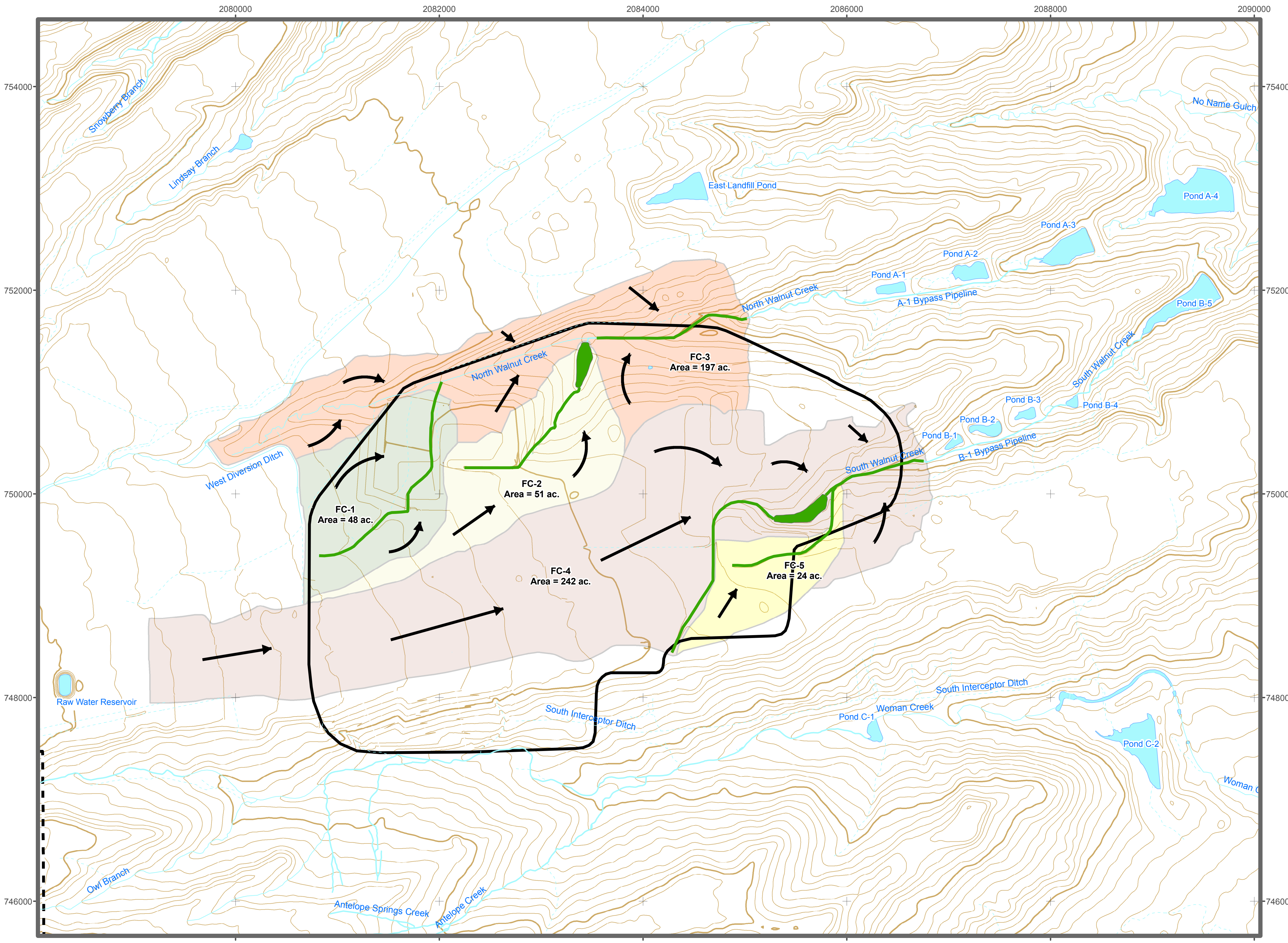
Figure 2.3

Overland Flow Directions



KEY

- General surface water runoff flow direction
- Functional channel (FC)
- Topographic contour (100 ft)
- Topographic contour (10 ft)

Standard Map Features

- IA OU boundary
- Pond
- Site boundary
- Perennial stream
- Intermittent stream
- Ephemeral stream

N
W E
S

0 500 1,000 Feet

Scale 1:12,000

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD 27

U.S. Department of Energy
Rocky Flats Environmental
Technology Site

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\ArcMap\Fig_2_03_Overlandflow.mxd

Easement Number	Easement Description
1	Natural gas pipeline
2	Natural gas pipeline
3	Natural gas pipeline
4	Natural gas pipeline
5	Oil and gas pipeline
6	Natural gas pipeline
7	Oil and gas pipeline
8	Oil and gas pipeline
9	Oil and gas pipeline
10	No documentation available for gas pipeline
11	Electric power and transmission line
12	Electric power and transmission line
13	Electric power and transmission line
14	Electric power and transmission line
15	Electric power and transmission line
16	Electric power and transmission line
17	Electric power and transmission line
18	Electric power line, no easement documents created
19	Electric power and transmission line and access road
20	Electric power and transmission line
21	Electric power transmission line and driveways
22	Access
23	Telecom to Building 060
24	License agreement to cross Boulder Ditch
25	Underground telecommunications cable
26	Underground telecommunications cable
27	Water conveyance pipeline
28	Telecommunications cable
29	Electric power line
30	DOE-owned electric power line
31	DOE-owned right-of-way for water pipeline and railroad spur

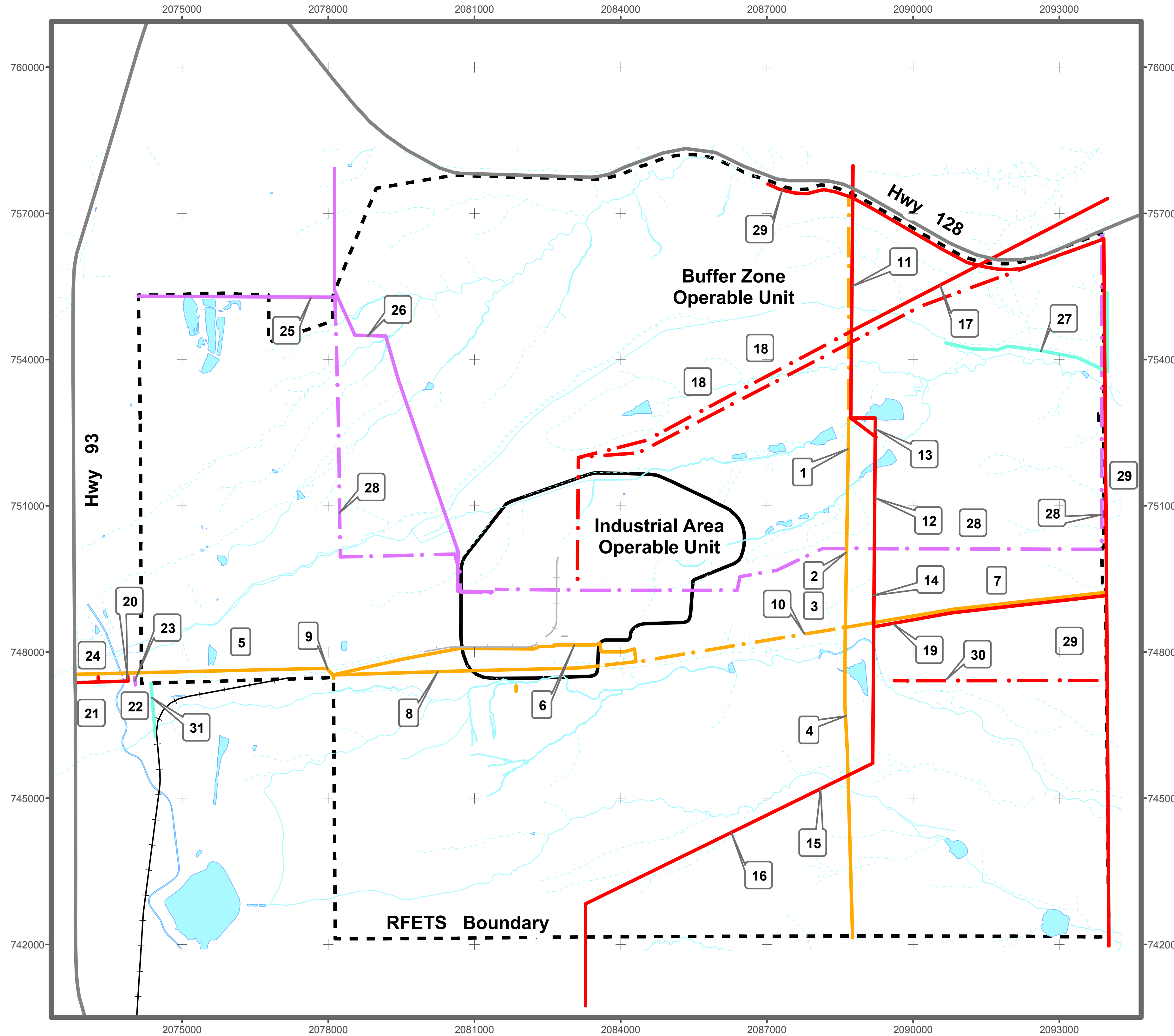


Figure 2.4

Easement Location Map

KEY

Regional roads
Electrical (no easement documents)
Electrical transmission easement
Railroad right-of-way
Site railroad
Raw water easement
Natural gas easement
Natural gas (no easement documents)
Telephone easement
Telephone (no easement documents)

Standard Map Features
IA OU boundary
Pond
Site boundary
Perennial stream
Intermittent stream
Ephemeral stream

N
W E
S

0 1,250 2,500 Feet

Scale 1:30,000

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD 27

U.S. Department of Energy
Rocky Flats Environmental Technology Site

File: W:\Projects\FY2005\RIFS_Fig\Sec02\ArcMap\Fig2_04Easements.mxd

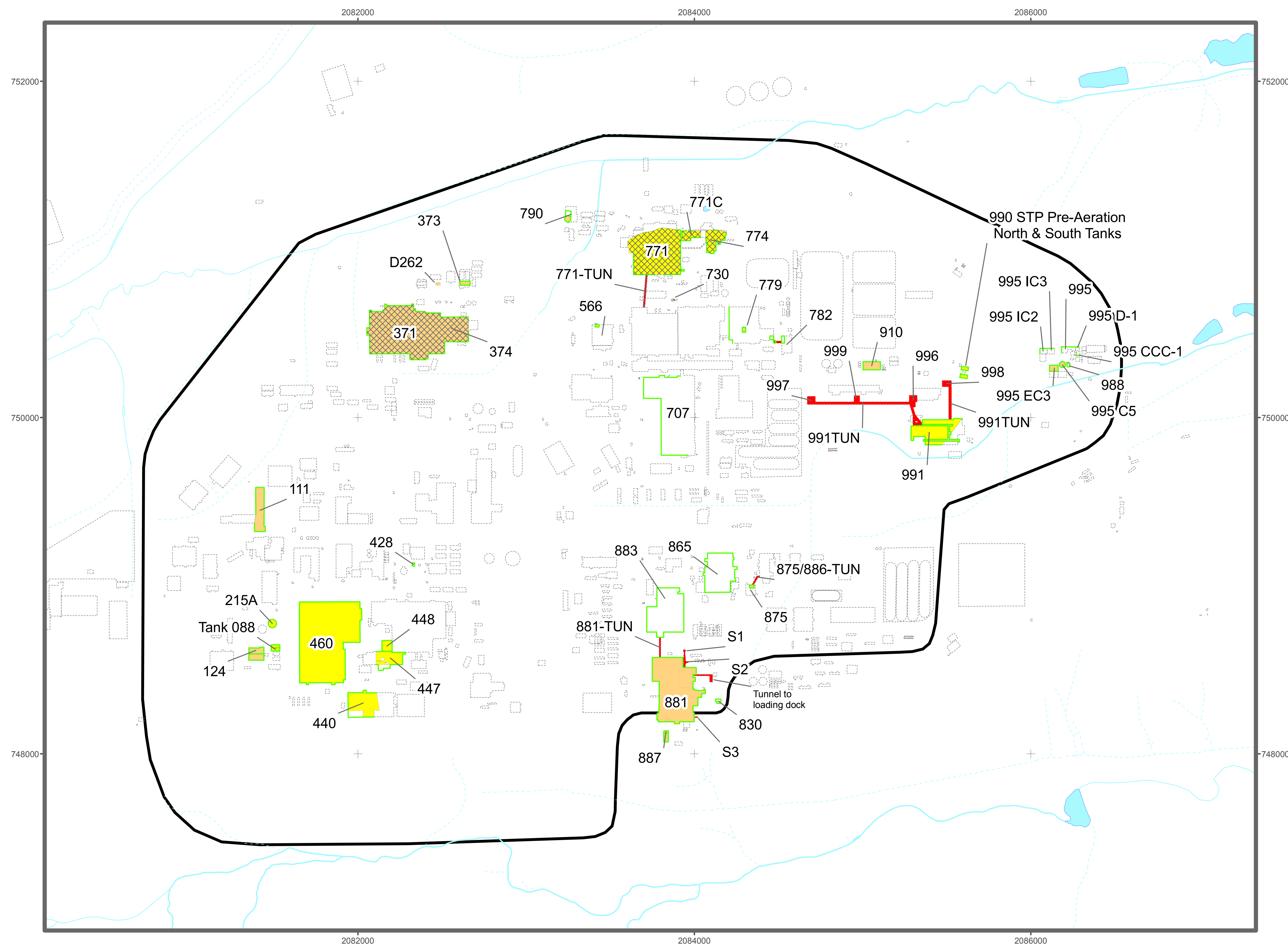


Figure 2.5

Subsurface Features After Accelerated Actions (Slabs, Building Foundations, and Tunnels)

KEY

- Slab remaining
- Basement slab remaining
- Tunnel Remaining (slab, walls, foundations, ceiling)
- Foundation Remaining (includes caissons and/or grade beams)
- Contaminated below 6 ft
- Removed buildings and structures

Standard Map Features

- IA OU boundary
- Pond
- Site boundary
- Perennial stream
- Intermittent stream
- Ephemeral stream

N
W E
S

0 300 600
Feet

Scale 1:7,200

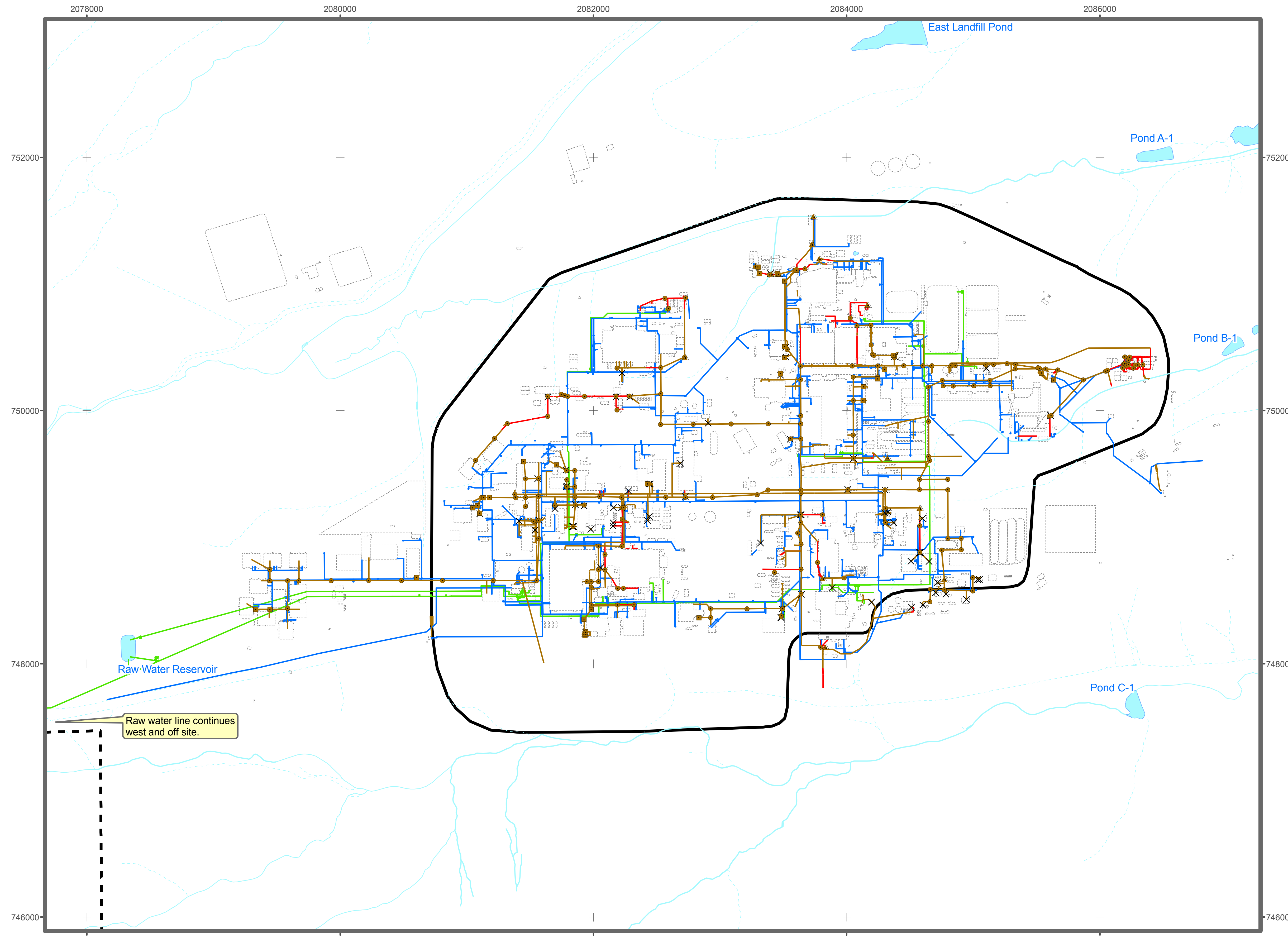
State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD 27

U.S. Department of Energy
Rocky Flats Environmental
Technology Site

File: W:\Projects\FY2005\RIFS_Fig\Sec02\ArcMap\Fig2_05_SubsurfaceFeaturesSlabs.mxd

Figure 2.6

Subsurface Features After Accelerated Actions (Sanitary Sewer Lines and Water Lines)



KEY

- Domestic cold water
- Raw water
- Sewer closed in place
- Sewer removed
- Sewer cut & cap
- Sewer manhole
- Sewer lift station
- Sewer cleanout
- Removed structure

Standard Map Features

- IA OU boundary
- Pond
- Site boundary
- Perennial stream
- Intermittent stream
- Ephemeral stream

N
W E
S

0 400 800
Feet

Scale 1:9,600

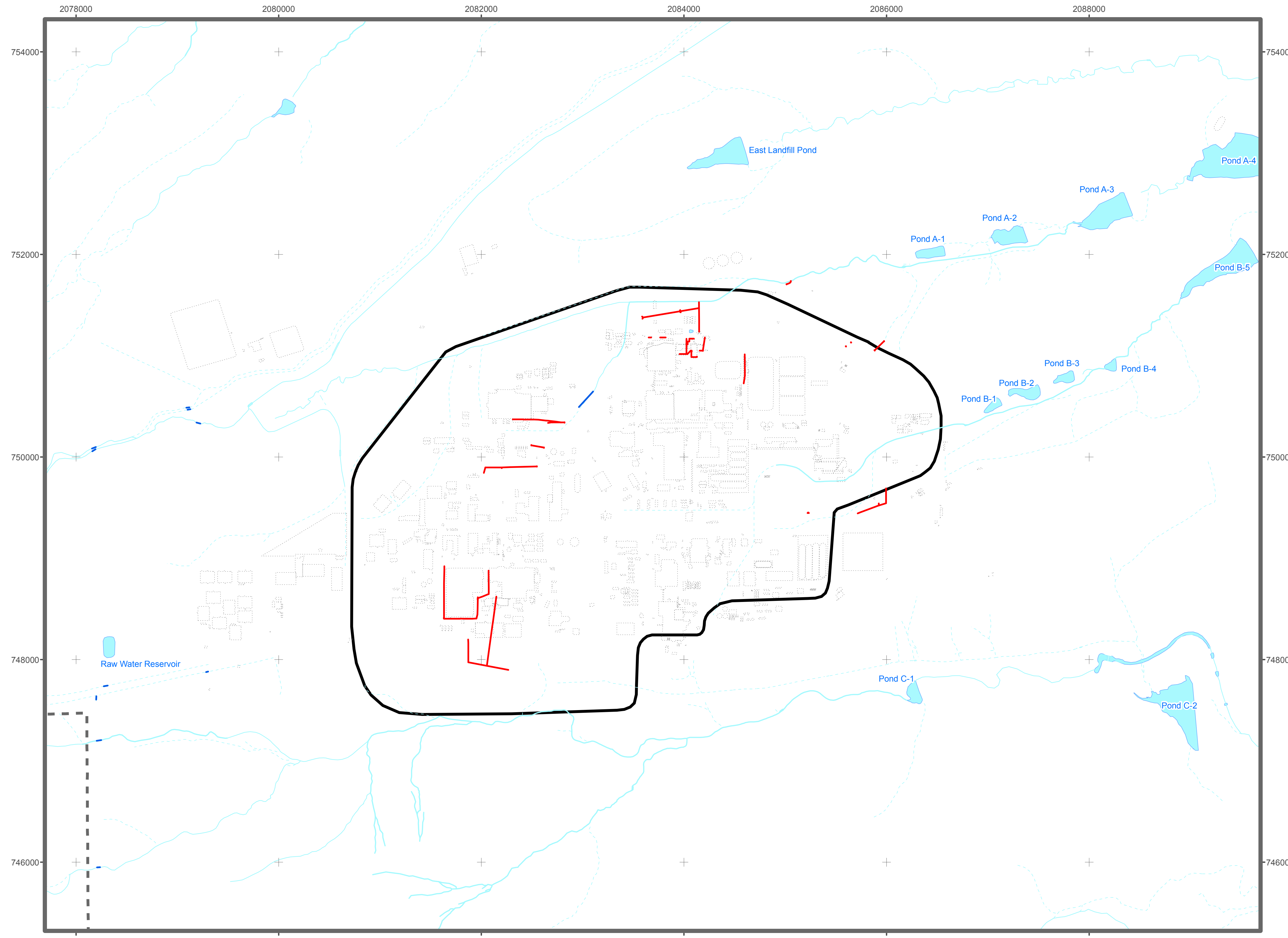
State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD 27

U.S. Department of Energy
Rocky Flats Environmental Technology Site

File: W:\Projects\FY2005\RIFS_Fig\Sec02\ArcMap\Fig2_06_SubsurfaceFeaturesSewerWater.mxd

Figure 2.7

Subsurface Features After Accelerated Actions (Culverts and Storm Drains)



KEY

- Culverts (retain and remain operational)
- Culverts and storm drains (retained and plugged ends)
- Removed structure

Standard Map Features

- IA OU boundary
- Pond
- Site boundary
- Perennial stream
- Intermittent stream
- Ephemeral stream

N
W E
S

0 600 1,200 Feet

Scale 1:12,000

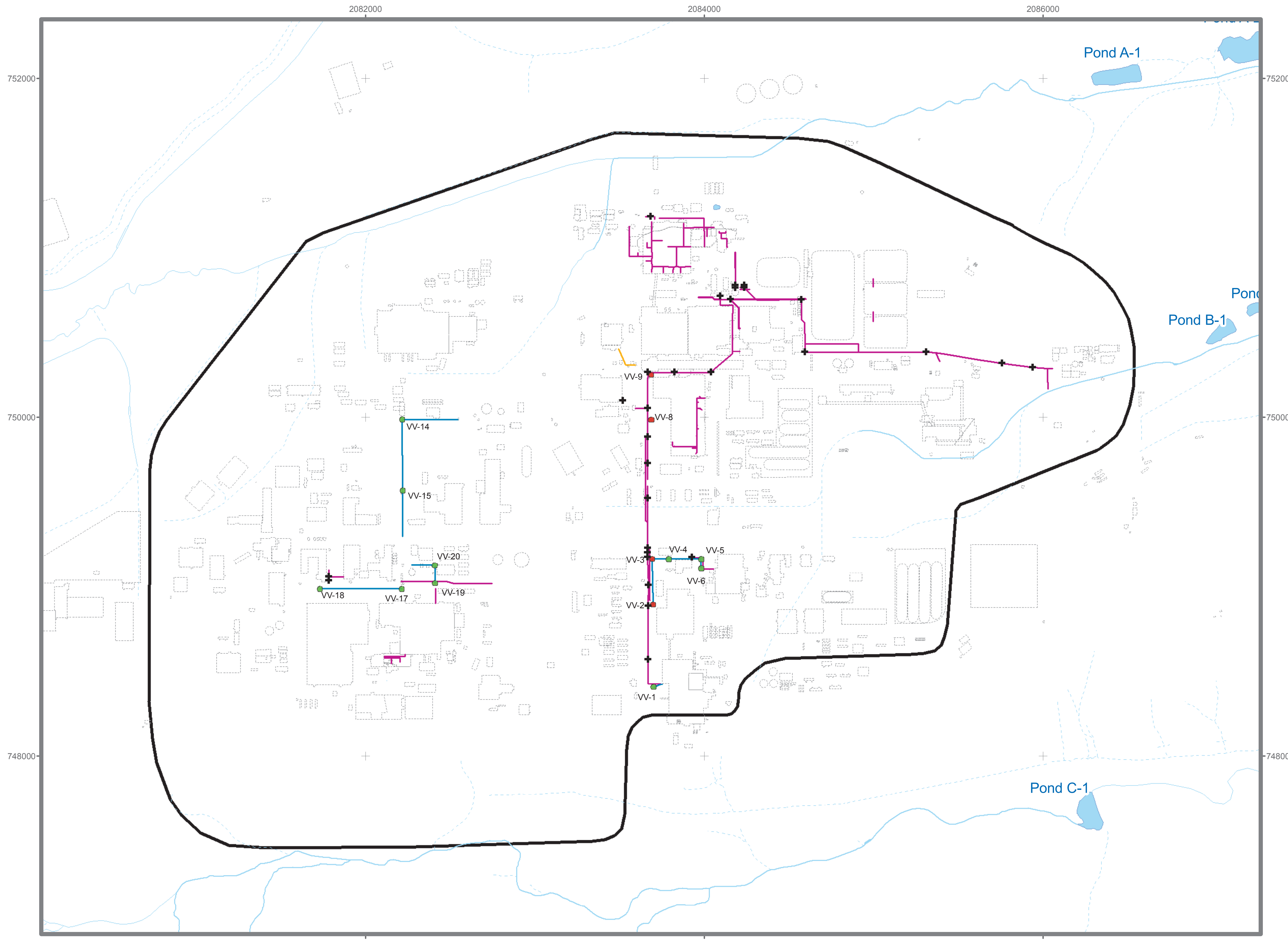
State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD 27

U.S. Department of Energy
Rocky Flats Environmental Technology Site

File: W:\Projects\FY2005\RIFS_Fig\Sec02\ArcMap\Fig2_07_SubsurfaceFeaturesCulverts.mxd

Figure 2.8

Subsurface Features After Accelerated Actions (Process Waste Lines and Valve Vaults)



KEY

Original Process Waste Lines (OPWL)

OPWL grouted and left in place

OPWL manway - removed

New Process Waste Lines (NPWL)

NPWL grouted and left in place clean closed

NPWL grouted and left in place not part of RCRA Unit 374.3

NPWL valve vault (removed to below 6 feet from surface and backfilled; not contaminated)

NPWL valve vault (removed to below 6 feet from surface and flowfilled/backfilled; radionuclide, contaminated)

Removed buildings and structures

Standard Map Features

IA OU boundary

Pond

Site boundary

Perennial stream

Intermittent stream

Ephemeral stream

N
W E
S

0 300 600
Feet

Scale 1:7,200

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD 27

U.S. Department of Energy
Rocky Flats Environmental Technology Site

File: W:\Projects\FY2005\RIFS_Fig\Sec02\ArcMap\Fig2_08_SubsurfaceFeaturesPWL-VV.mxd

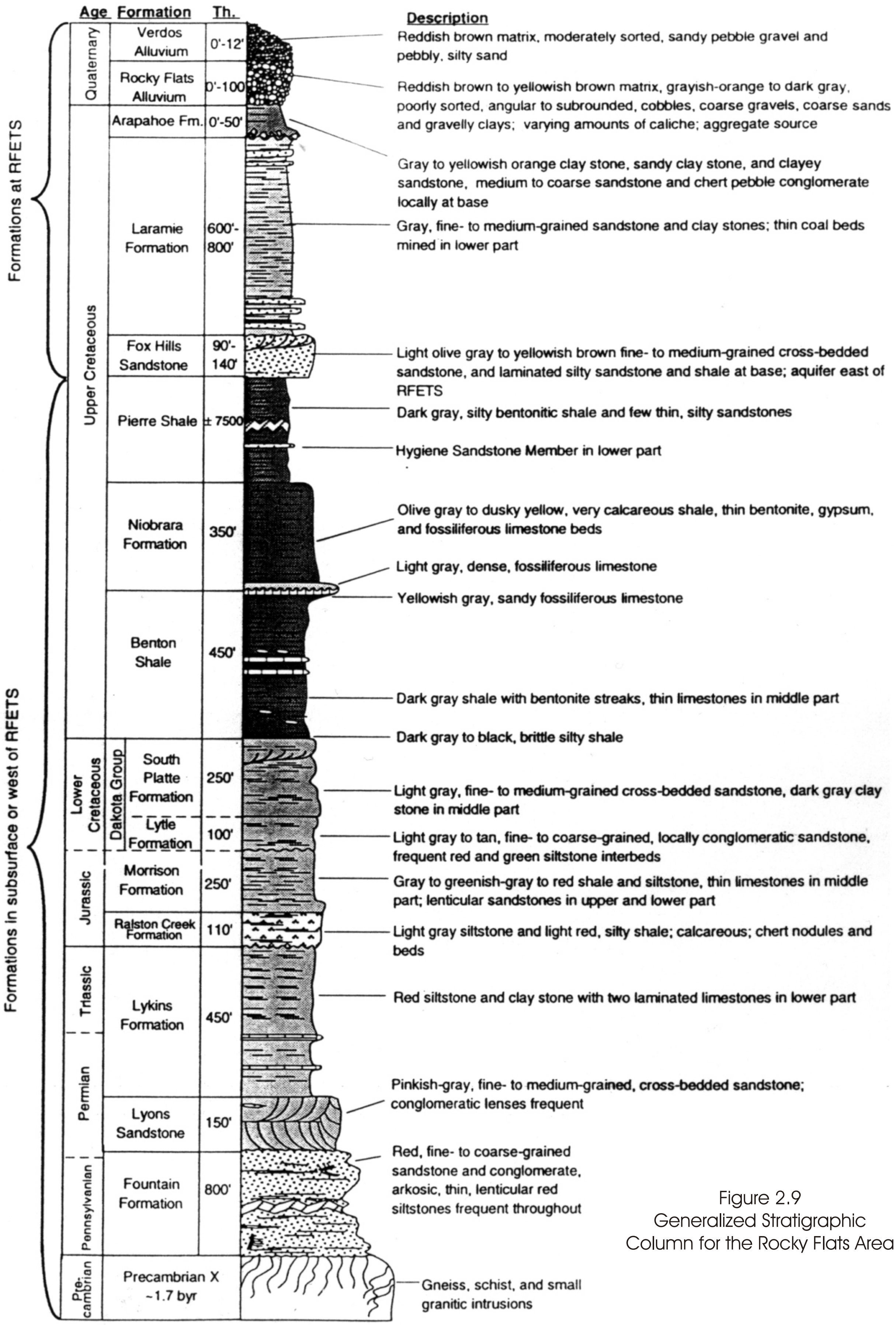


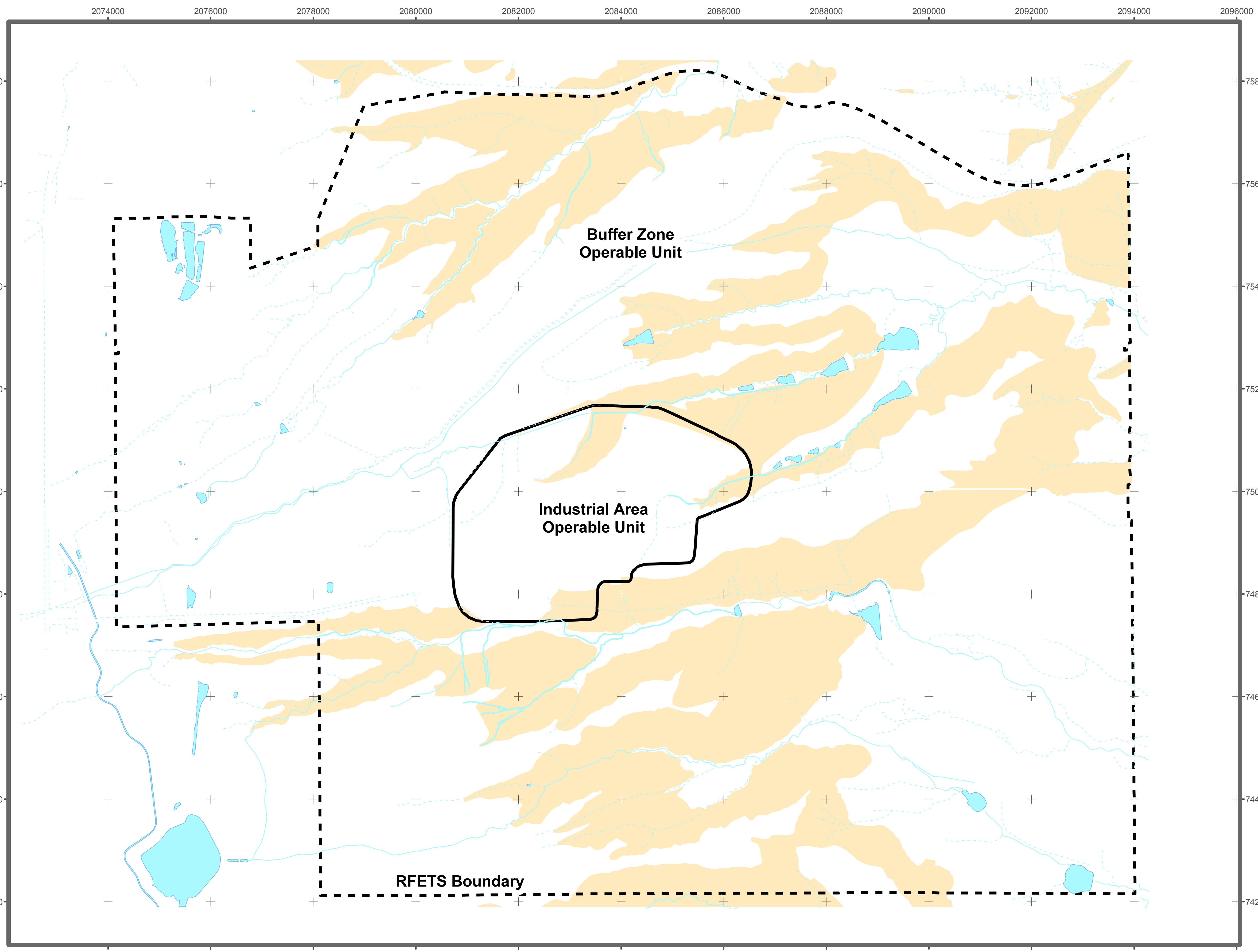
Figure 2.9
Generalized Stratigraphic
Column for the Rocky Flats Area

Modified from LeRoy and Weimer (1971)

\\gissrv\ER\Projects\FY2005\RIFS_Fig\Sec02\Corel_Draw\Fig2_9GeneralizedStratigraphic.cdr

Figure 2.10

Landslide and High Erosion Areas



KEY

Areas of landslide and high erosion

Source: RFCA Attachment 5 (May 28, 2003)

Standard Map Features

IA OU boundary

Pond

Site boundary

Perennial stream

Intermittent stream

Ephemeral stream

N
W E
S

0 1,000 2,000 Feet

Scale 1:24,000

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD 27

U.S. Department of Energy
Rocky Flats Environmental
Technology Site

File: W:\Projects\FY2005\RIFS_Fig\Sec02\ArcMap\Fig2_10Erosion.mxd

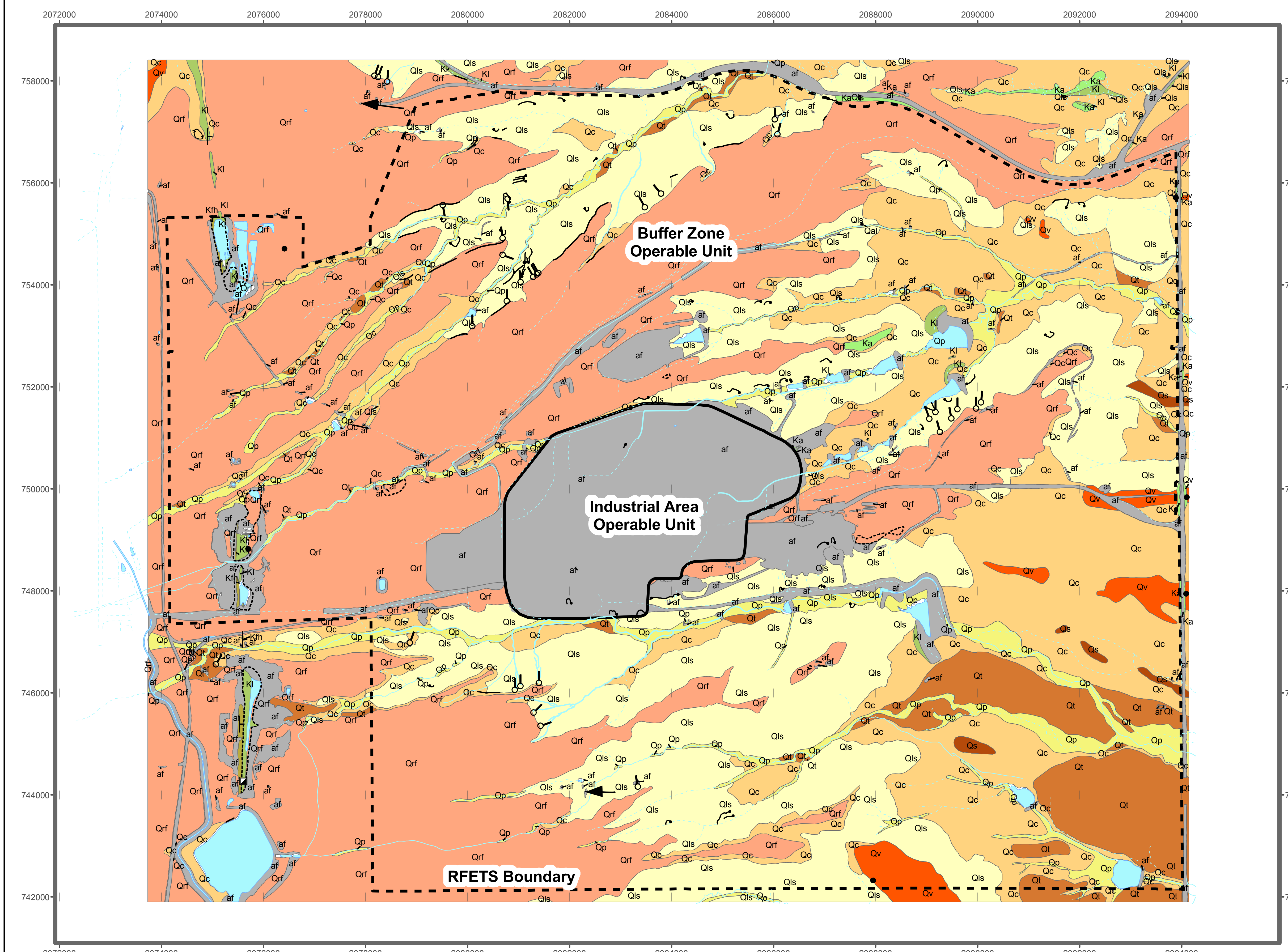


Figure 2.11
Geologic Units at Rocky Flats Environmental Technology Site (Produced in Cooperation with the USGS)

KEY

Geology
- af- Artificial fill or disturbed area
- Qp - Post-Piney Creek/Piney Creek Alluvium
- Qt - Terrace Alluviium
- Qc - Colluvium
- Qls - Landslide deposits
- Qs - Slocum Alluvium
- Qv - Verdos Alluvium
- Qrf - Rocky Flats Alluvium
- Ka - Arapahoe Formation
- Kl - Laramie Formation
- Kfh - Fox Hill Sandstone

Geomorphology Line
- Areas of vegetation at and near springs
- Boundary of gravel and clay pit
- Scarp of young landslide
- Shallow closed depression

Geomorphology Point
- Spring
- Strike and dip of beds
- Clast identification site
- Capitol Mine (abandoned)

Note:
Industrial Area soil disturbance reflects changes to USGS survey results based on soil disturbance after the USGS study was completed. Artificial fill area based on assumption that all of the IA OU has disturbed soil.

Data Source:
Geologic Mapping: Shroba, R.R., and Carrara, P.E. Preliminary Surficial Map of the Rocky Flats Plant and Vicinity, Jefferson and Boulder Counties, Colorado: U.S. Geological Survey Open-File Report (OFR) 94-162, Scale 1:6000. Site source of topo base; see OFR 94-162 (on map).

Standard Map Features
- IA OU boundary
- Pond
- Site boundary
- Perennial stream
- Intermittent stream
- Ephemeral stream

N
W E
S

0 1,000 2,000 Feet

Scale 1:24,000

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD 27

U.S. Department of Energy
Rocky Flats Environmental Technology Site

File: W:\Projects\FY2005\RIFS_Fig\Sec02\ArcMap\Fig2_11_geology_Tabloid.mxd

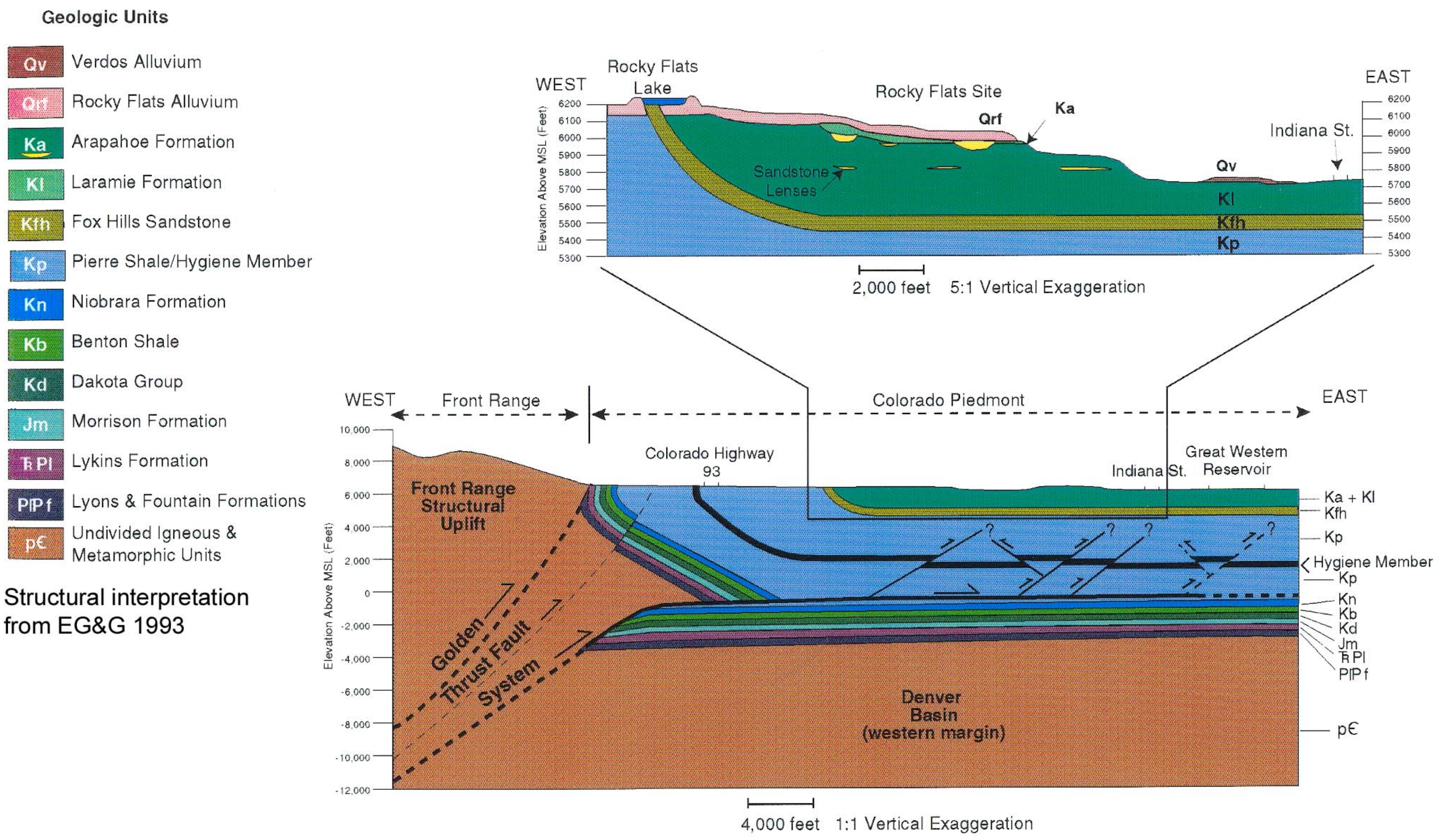
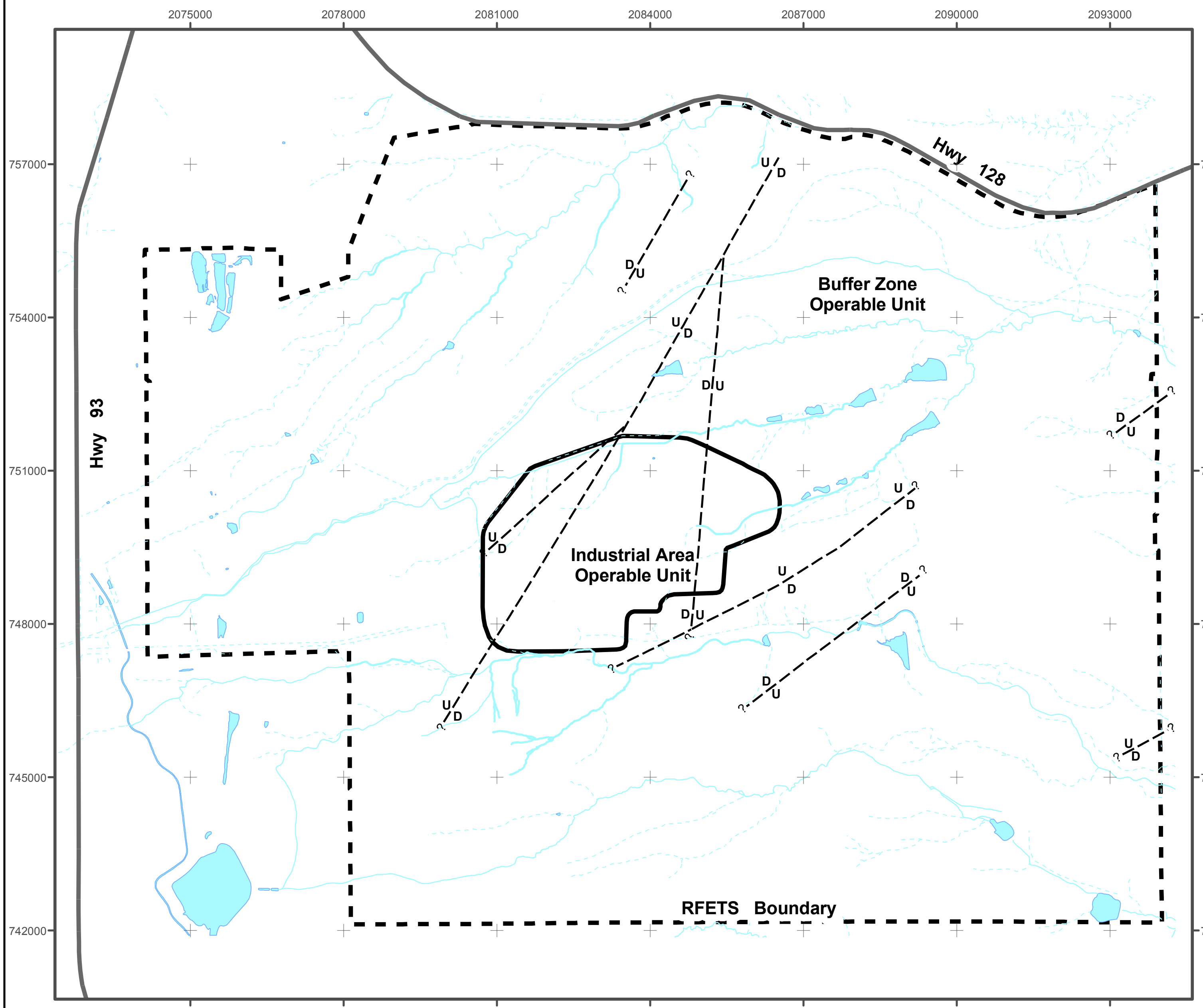


Figure 2.12

Generalized Geologic Cross Section of the Front Range and Rocky Flats Area

Figure 2.13

Inferred Fault Locations



KEY

- Inferred geologic fault
- D Downthrown side of fault
- U Upthrown side of fault
- ? Location approximate

Source:
Adapted from Plate 7-1, Geologic Characterization Report (EG&G 1995a)

Standard Map Features

- IA OU boundary
- Pond
- Site boundary
- Perennial stream
- Intermittent stream
- Ephemeral stream

N W E S

0 1,500 3,000 Feet

Scale 1:36,000

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD 27

U.S. Department of Energy
Rocky Flats Environmental Technology Site

File: W:\Projects\FY2005\RIFS_Fig\Sec02\ArcMap\Fig2_13FaultLocations.mxd

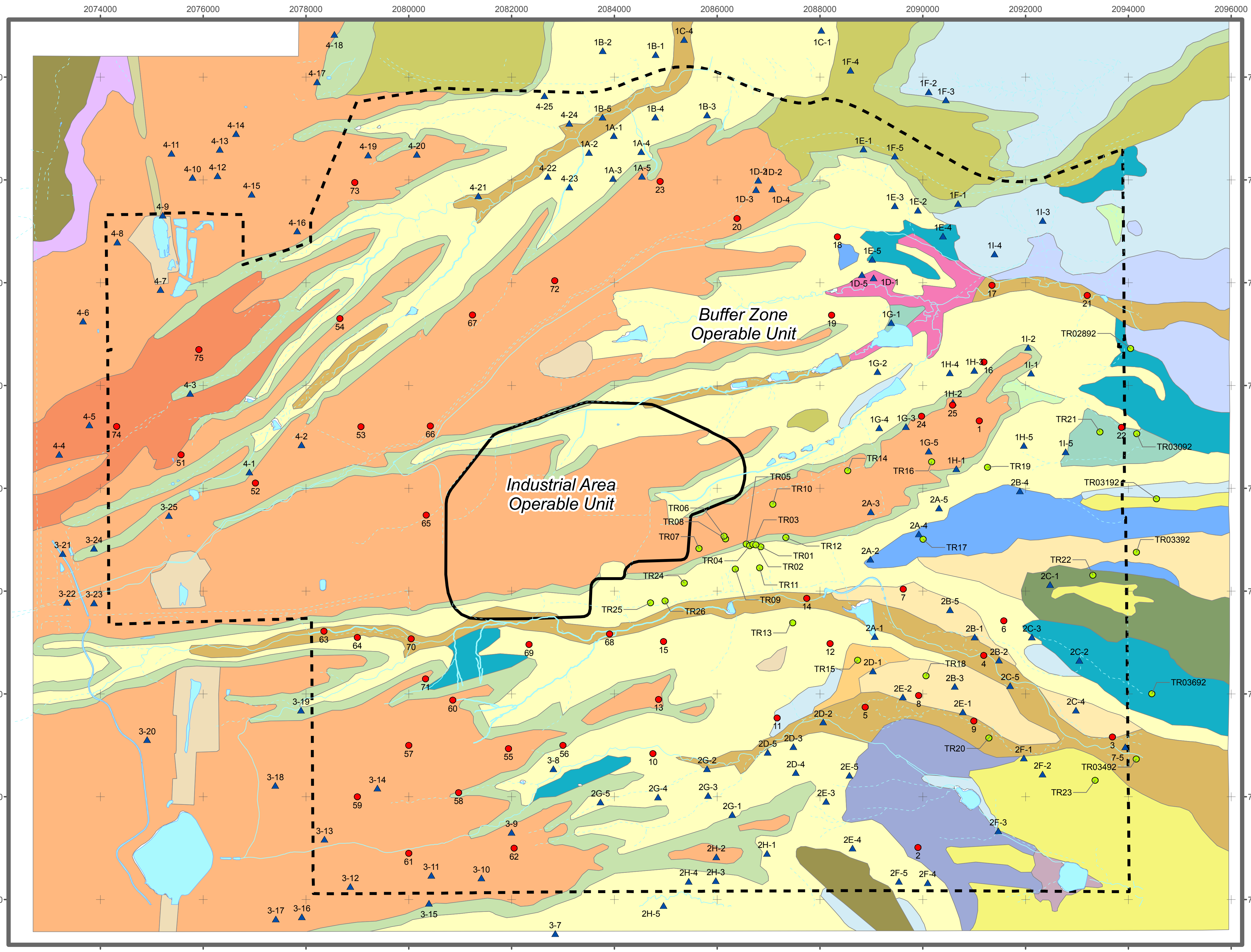


Figure 2.14 Rocky Flats Soils Map With Hydraulic Conductivity Measurements and Soil Sampling Locations

KEY

- Tension infiltrometer sampling location
- Soil pit location
- CDPHE sampling location

Soil (Numbers in parentheses indicate % slope)

- Denver clay loam (2 - 5%)
- Denver clay loam (5 - 9%)
- Denver-Kutch clay loam (5 - 9%)
- Denver-Kutch-Midway clay loam (9 - 15%)
- Denver-Kutch-Midway clay loam
- Englewood clay loam (0 - 2%)
- Englewood clay loam (2 - 5%)
- Flatirons cobbly sandy loam (0 - 3%)
- Flatirons stoney sandy loam (0 - 5%)
- Haverson loam (0 - 3%)
- Leyden-Primen-Standley cobbly clay loam (15 -50%)
- McClave clay loam (0 - 3%)
- Midway clay loam (9 - 30%)
- Nederland very cobbly sandy loam (15 - 50%)
- Nunn clay loam (0 - 2%)
- Nunn clay loam (2 - 5%)
- Pits (gravel)
- Rock outcrop (Sedimentary)
- Standley-Nunn gravelly clay loam (0 - 5%)
- Valmont clay loam (0 - 3%)
- Veldkamp-Nederland very cobbly sandy loam (0 - 3%)
- Willowman-Leyden cobbly loam (9 - 30%)
- Yoder Variant-Midway complex (15 - 60%)

Note: Soil in the Industrial Area Operable Unit was widely disturbed and may not be represented by 1980 soil survey results.

Data Source:
Soils data from the U.S. Conservation Service.
Uncertified Golden Area Soil survey - 1980.

Standard Map Features

- IA OU boundary
- Pond
- Site boundary
- Perennial stream
- Intermittent stream
- Ephemeral stream

N
W E
S

0 1,000 2,000
Feet

Scale 1:24,000

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD 27

U.S. Department of Energy
Rocky Flats Environmental
Technology Site

File: W:\Projects\FY2005\RIFS_Fig\Sec02\ArcMap\Fig2_14_Soils_Hydraulic-conductivity.mxd

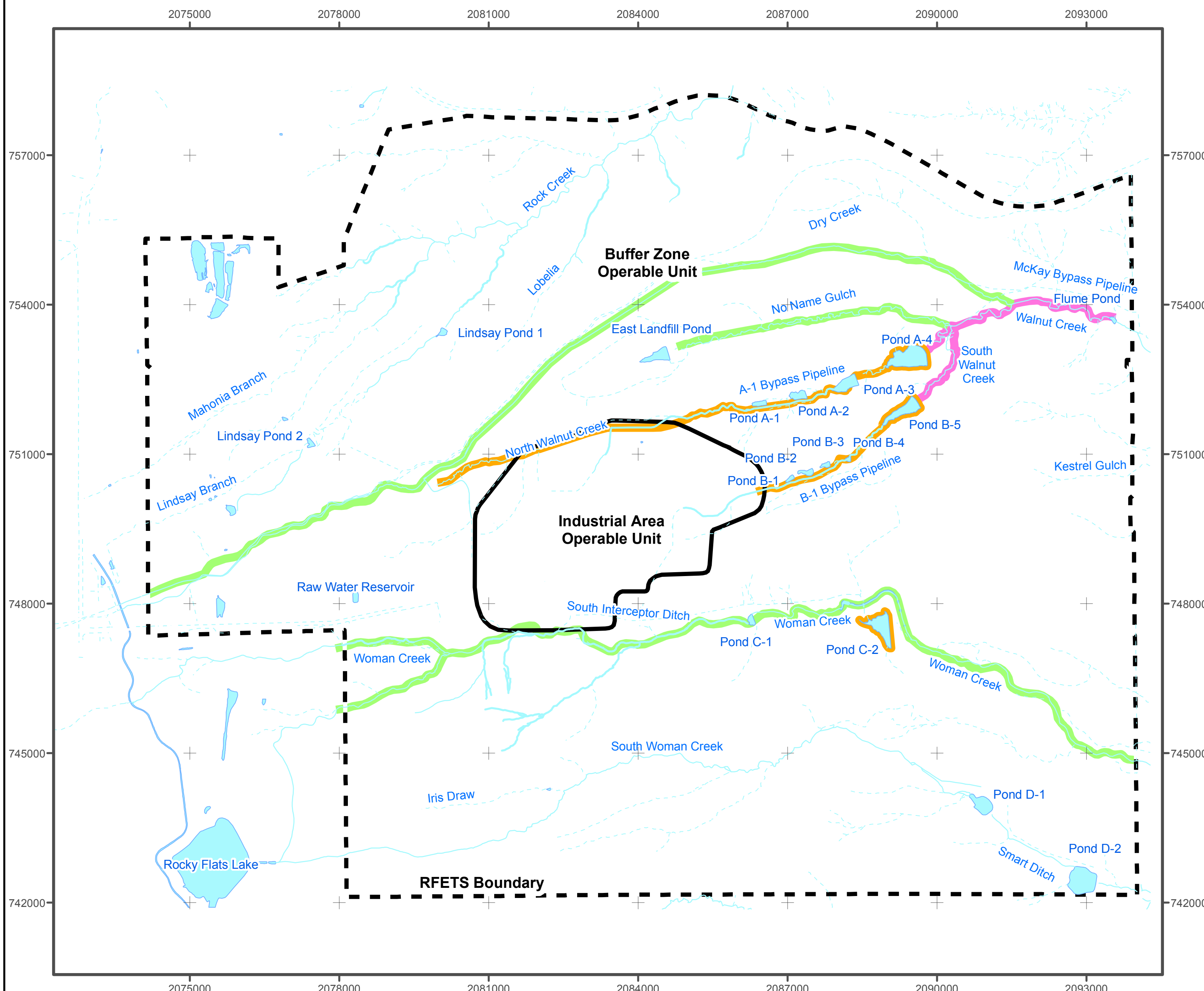


Figure 2.15
Colorado Water Quality Control Commission (CWQCC) Stream Segment Classifications
(Big Dry Creek Basin)

KEY

Stream Segment
- 4a
- 4b
- 5

Notes:
1) Rock Creek is designated as segment 8 of the Boulder Creek basin.
2) South Woman Creek, including the Smart Ditches, is designated as segment 6 of the Big Dry Creek basin.

Standard Map Features
- IA OU boundary
- Pond
- Site boundary
- Perennial stream
- Intermittent stream
- Ephemeral stream

N
W
E
S

0 1,500 3,000 Feet

Scale 1:36,000

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD 27

U.S. Department of Energy
Rocky Flats Environmental Technology Site

File: W:\Projects\FY2005\RIFS_Fig\Sec02\ArcMap\Fig2_15StreamSegments.mxd

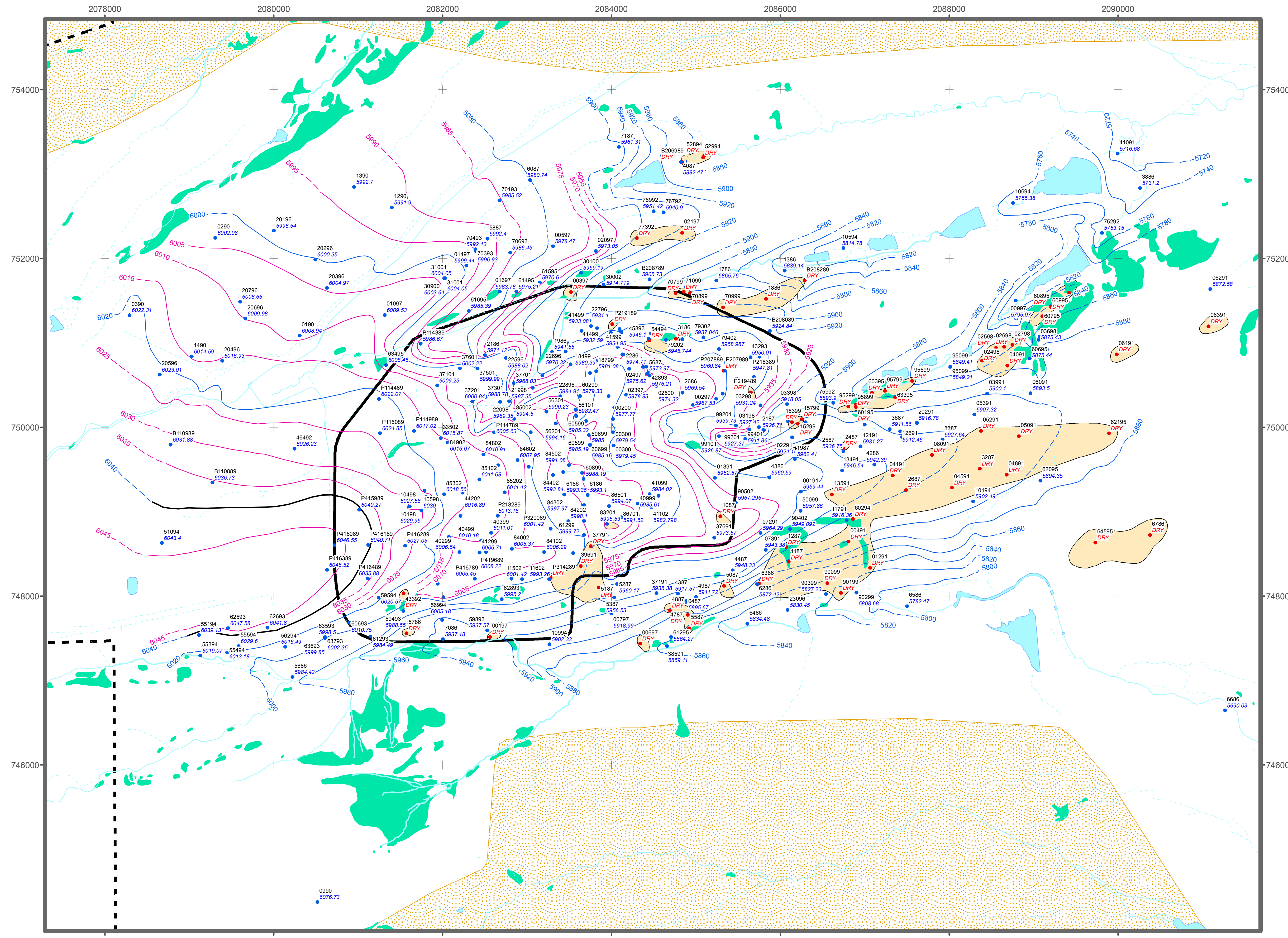


Figure 2.16

Potentiometric Surface of Permeable Units of the UHSU Second Quarter (2003)

KEY

- Well with water level
- Dry well
- Potentiometric contour (5 ft)
- Inferred potentiometric contour (5 ft)
- Potentiometric contour (20 ft)
- Inferred potentiometric contour (20 ft)
- Seeps
- Approximate extent of unsaturated alluvium
- Areas without groundwater elevations

Standard Map Features

- IA OU boundary
- Pond
- Site boundary
- Perennial stream
- Intermittent stream
- Ephemeral stream

N
W E
S

0 600 1,200
Feet

Scale 1:14,400

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD 27

U.S. Department of Energy
Rocky Flats Environmental
Technology Site

File: W:\Projects\FY2005\RIFS_Fig\Sec02\ArcMap\Fig2_16Potentio2q03.mxd

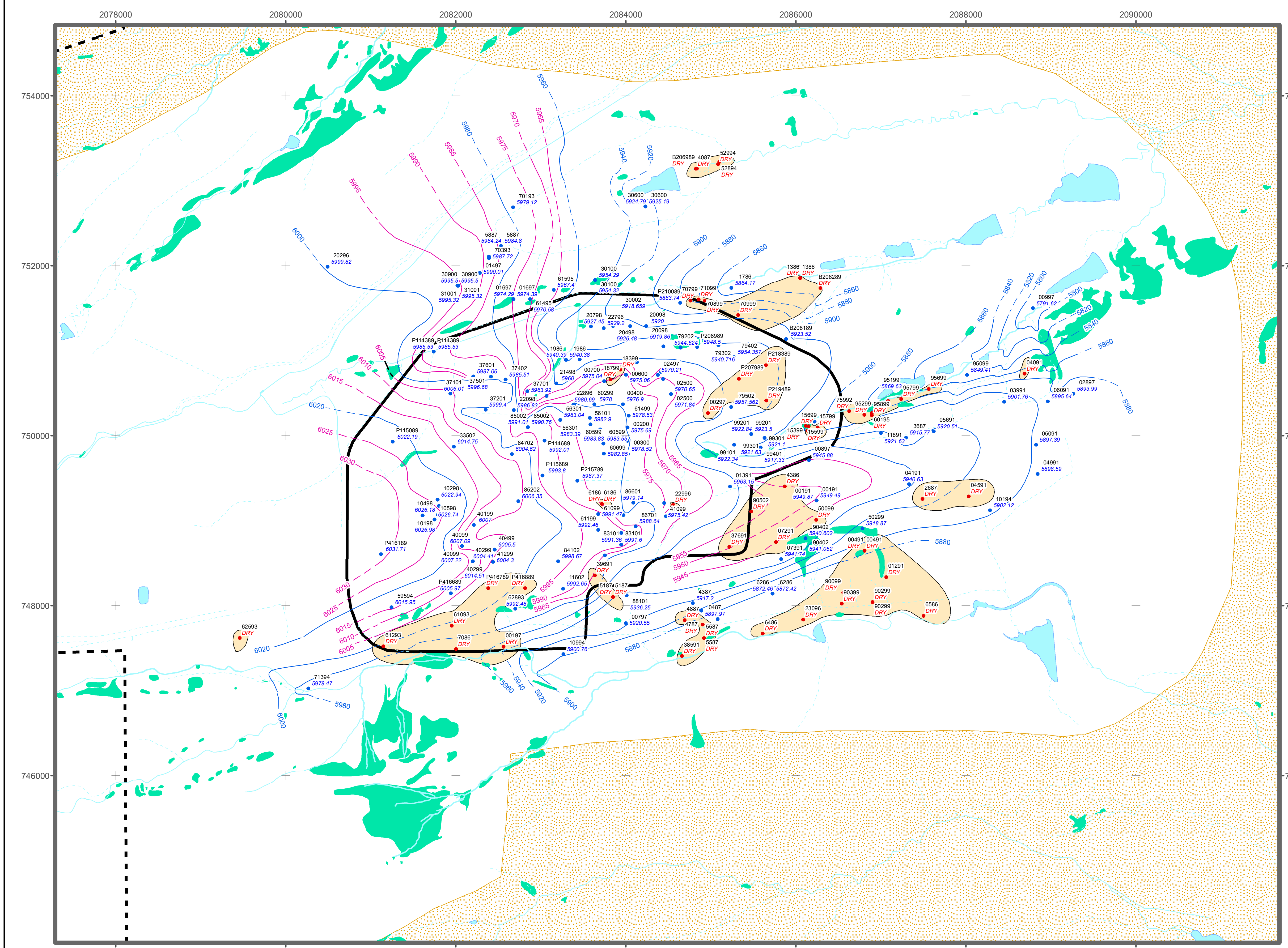


Figure 2.17

Potentiometric Surface of Permeable Units of the UHSU Fourth Quarter (2003)

KEY

- Well with water level
- Dry well
- Potentiometric contour (5 ft)
- Inferred potentiometric contour (5 ft)
- Potentiometric contour (20 ft)
- Inferred potentiometric contour (20 ft)
- Seeps
- Approximate extent of unsaturated alluvium
- Areas without groundwater elevations

Standard Map Features

- IA OU boundary
- Pond
- Site boundary
- Perennial stream
- Intermittent stream
- Ephemeral stream

N
W E
S

0 600 1,200
Feet

Scale 1:14,400

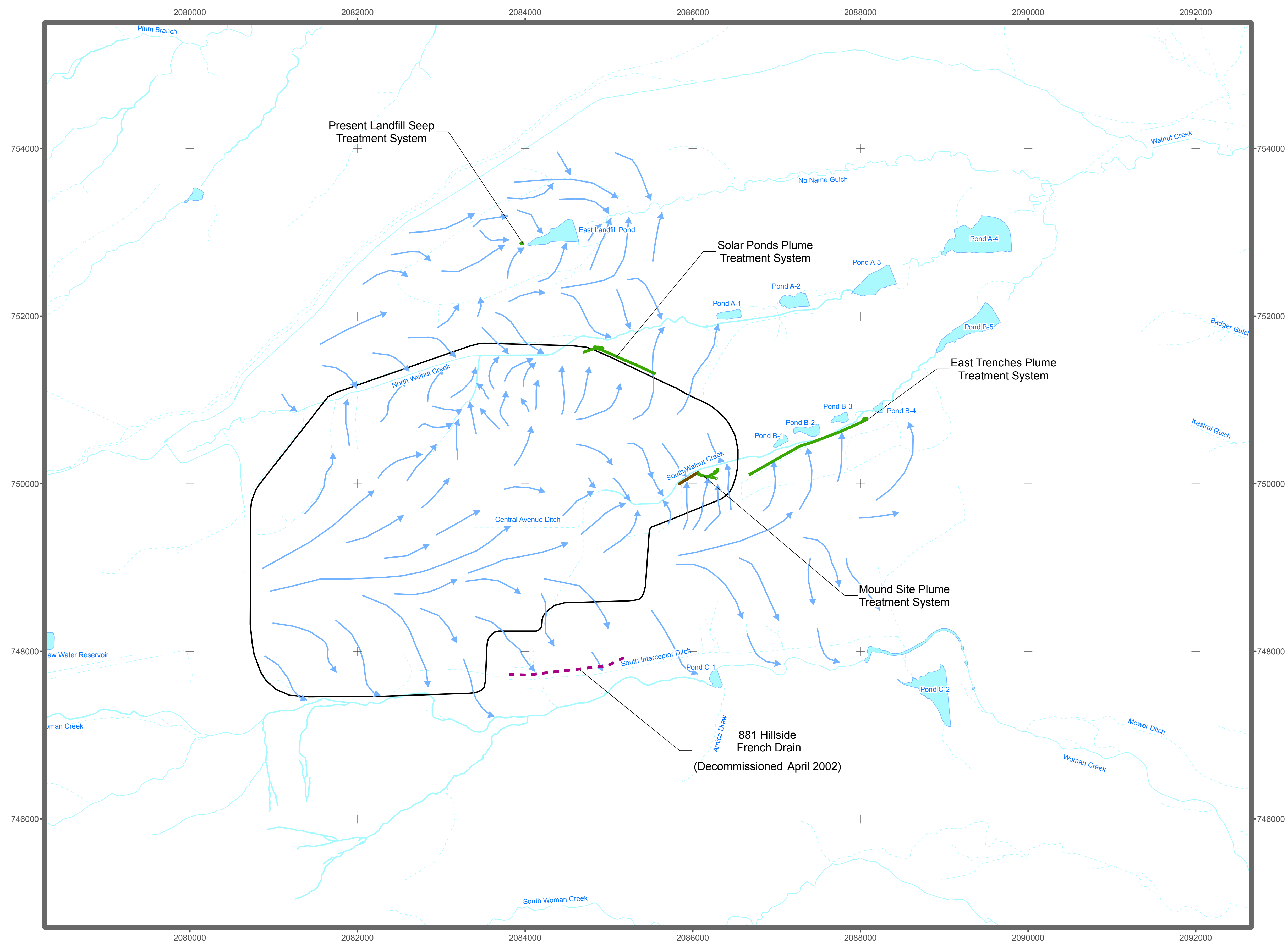
State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD 27

U.S. Department of Energy
Rocky Flats Environmental
Technology Site

File: W:\Projects\FY2005\RIFS_Fig\Sec02\ArcMap\Fig2_17Potentio4q03.mxd

Figure 2.18

Predicted Groundwater Flow Directions



KEY

- Predicted groundwater flow direction
- Existing groundwater treatment system
- Decommissioned french drain
- Mound french drain
- IA OU boundary

Note:
The length of the arrow does not correspond to the groundwater velocity.

Standard Map Features

- Pond
- Perennial stream
- Intermittent stream
- Ephemeral stream

N W E S

0 600 1,200 Feet

Scale 1:14,400

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD 27

U.S. Department of Energy
Rocky Flats Environmental Technology Site

File: W:\Projects\FY2005\RIFS_Fig\Sec02\ArcMap\Fig2_18_GWFlowDir.mxd

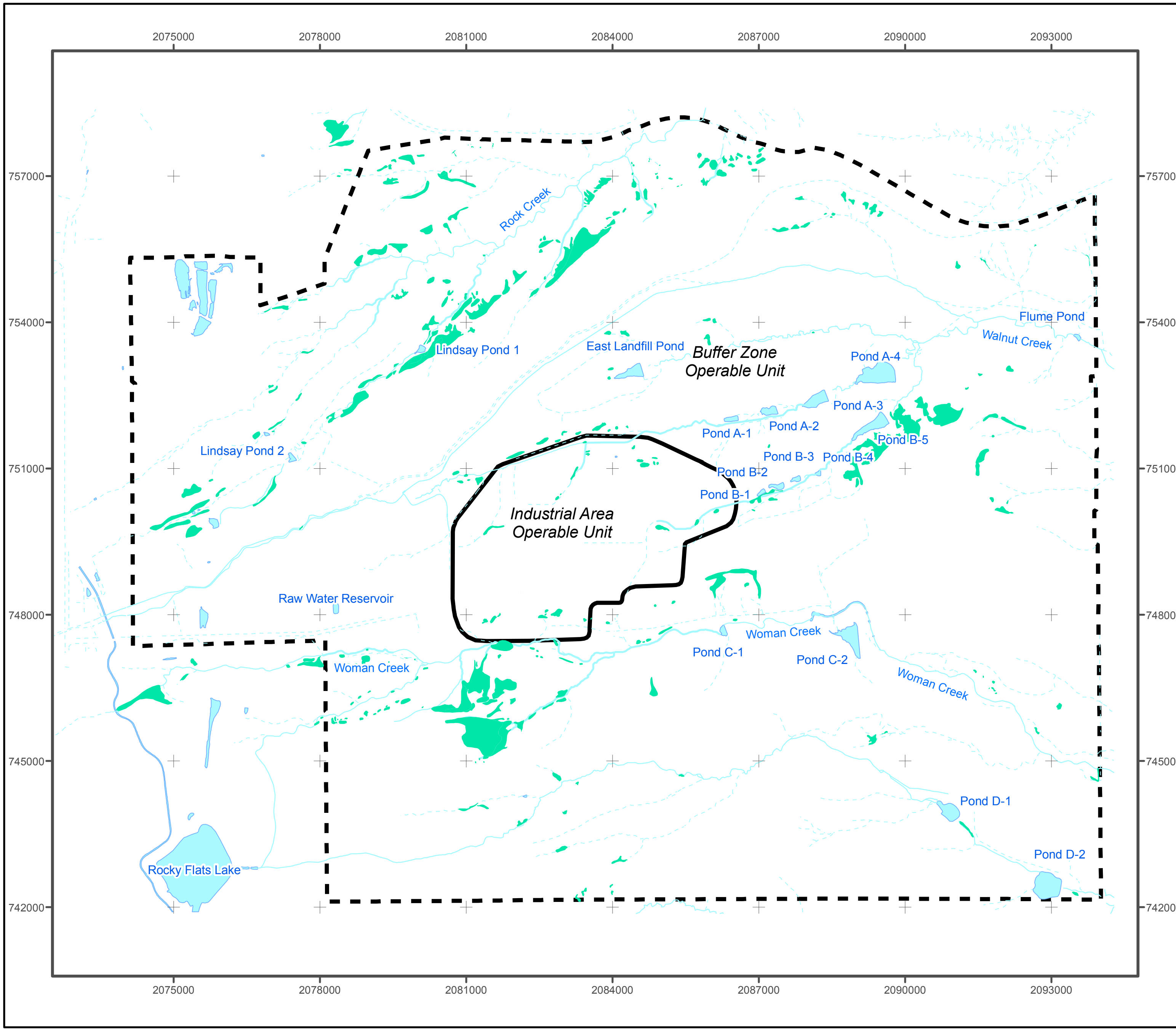


Figure 2.19

Seep Areas

KEY

Seeps

Data Source:
Seep locations from EG&G 1995b, Hydrogeologic Characterization Report for the Rocky Flats Environmental Technology Site

Standard Map Features

IA OU boundary

Pond

Site boundary

Perennial stream

Intermittent stream

Ephemeral stream

N W E S

0 1,500 3,000 Feet

Scale 1:36,000

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD 27

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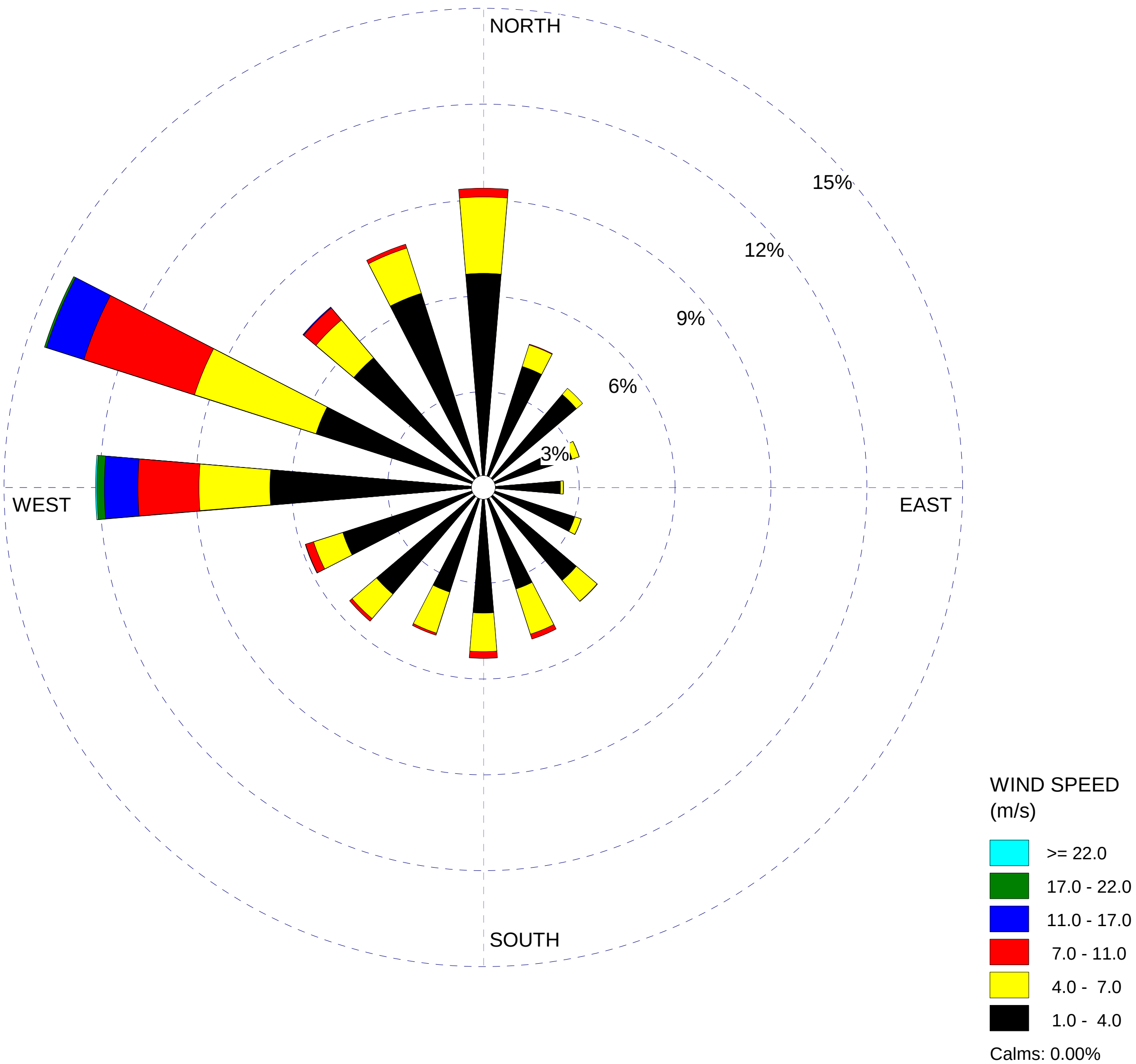
Rocky Flats Environmental Technology Site

File: W:\Projects\FY2005\RIFS_Fig\Sec02\ArcMap\Fig2_19SeepAreas.mxd

Figure 2.20
Wind Speed and Direction - 2004



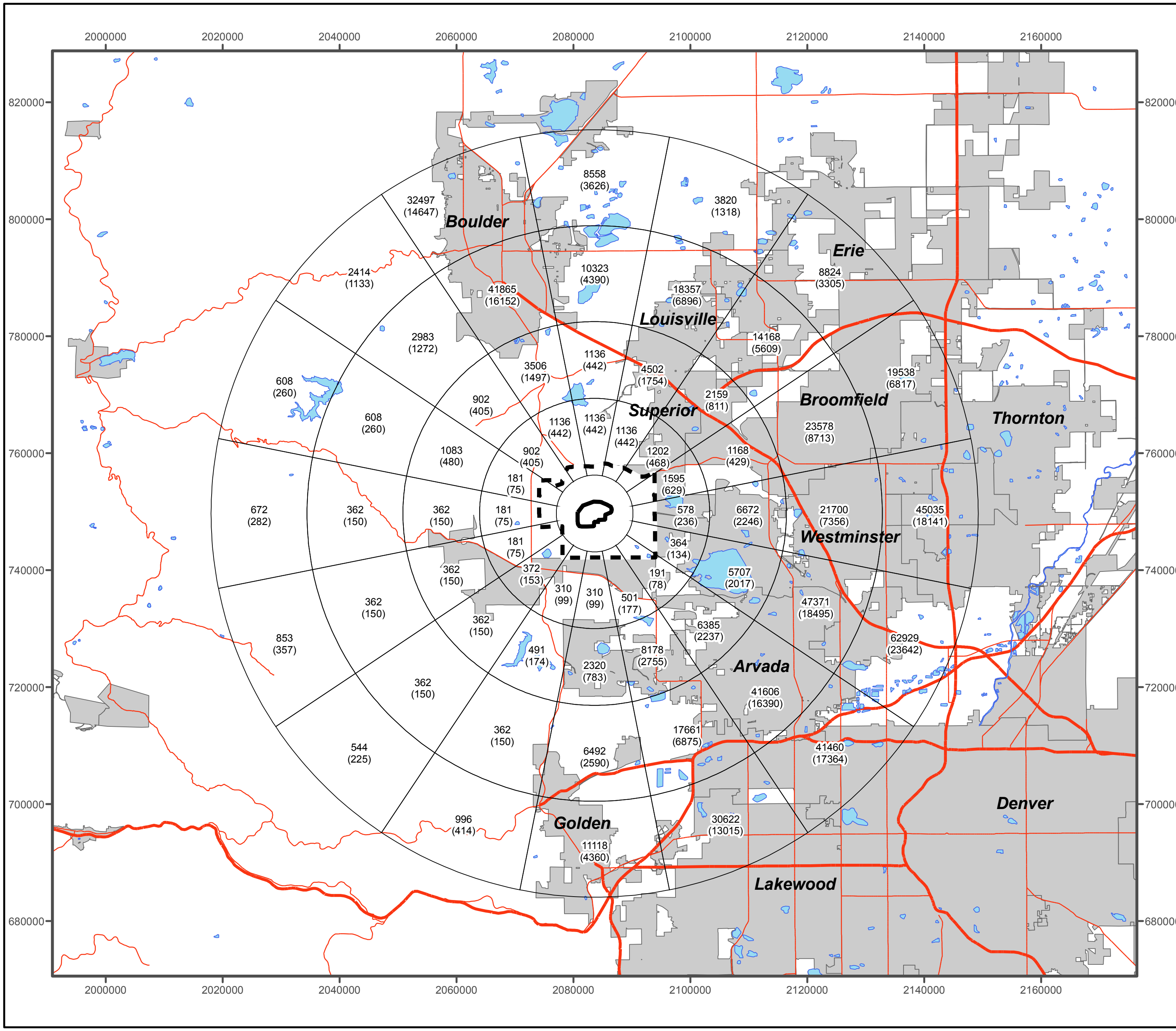


Figure 2.21
Population Distribution - 2004

KEY

- Population distribution
- Waterbodies
- Site boundary
- City boundary
- IA OU boundary

Major Transportation Routes

- Other
- Interstate

Note:
The center of the pie chart is the location of the former Industrial Area at the Rocky Flats Environmental Technology Site. The numbers represent the population of each pie area. The numbers in parentheses represent the number of households.

N
W E
S

0 12,500 25,000 Feet

Scale 1:300,000

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD 27

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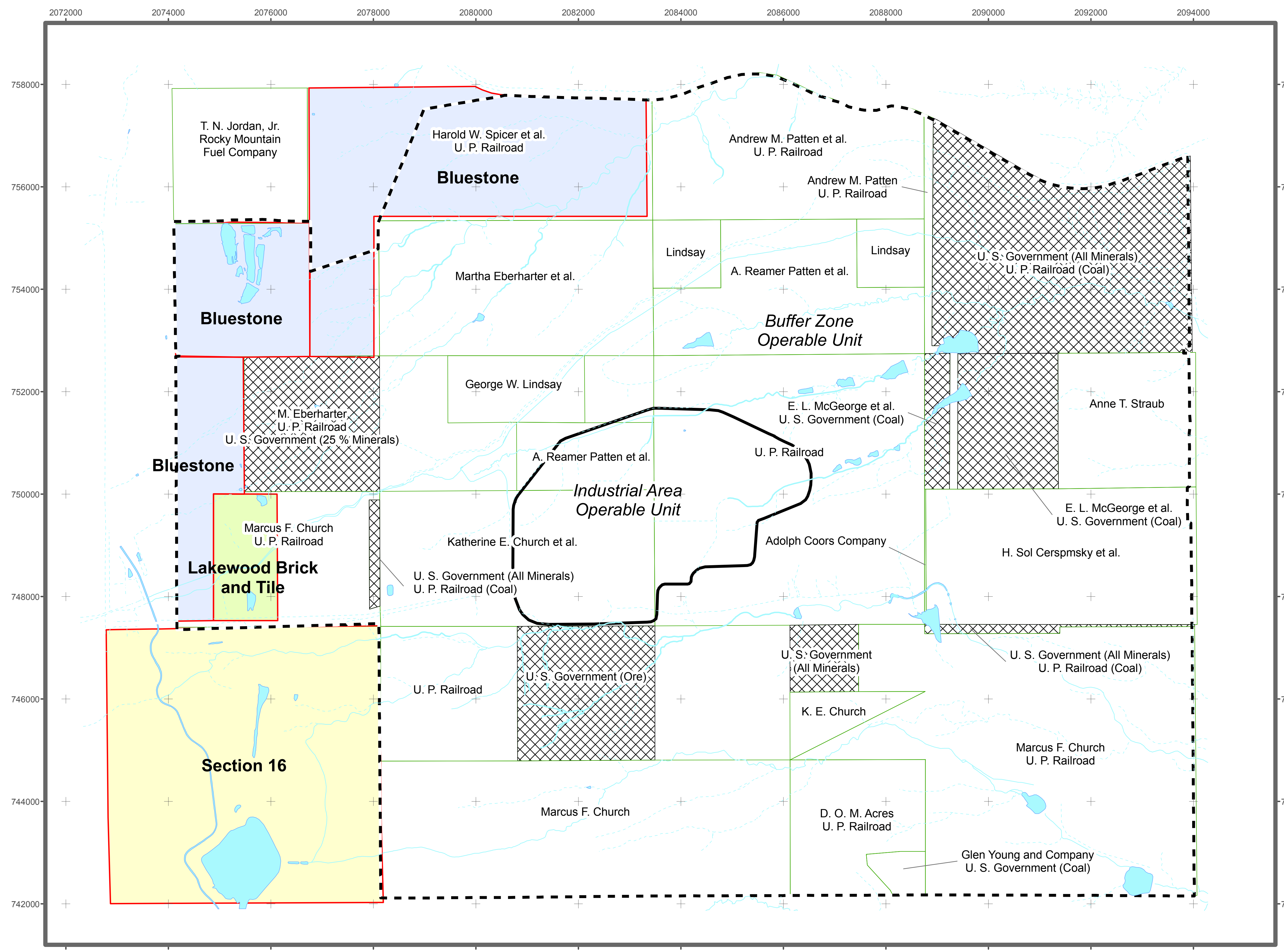
File: W:\Projects\FY2005\RIFS_Fig\Sec02\ArcMap\Fig2_21_PopulationDistribution2004.mxd

Figure 2.22
Mineral Rights at the Rocky Flats Environmental Technology Site



KEY

- Existing mining permit
- Mineral right boundary
- Government
- Lakewood Brick & Tile
- Bluestone
- Section 16

Data Source:
Mineral Right's Lease Boundaries approved by RFCSS Facility Planning Department., POC Norm Sprolas, 303-966-2303

Standard Map Features

- IA OU boundary
- Pond
- Site boundary
- Perennial stream
- Intermittent stream
- Ephemeral stream

N
W E
S

0 1,000 2,000 Feet

Scale 1:24,000

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD 27

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Technology Site

File: W:\Projects\FY2005\RIFS_Fig\Sec02\ArcMap\Fig2_22_MineralRights.mxd

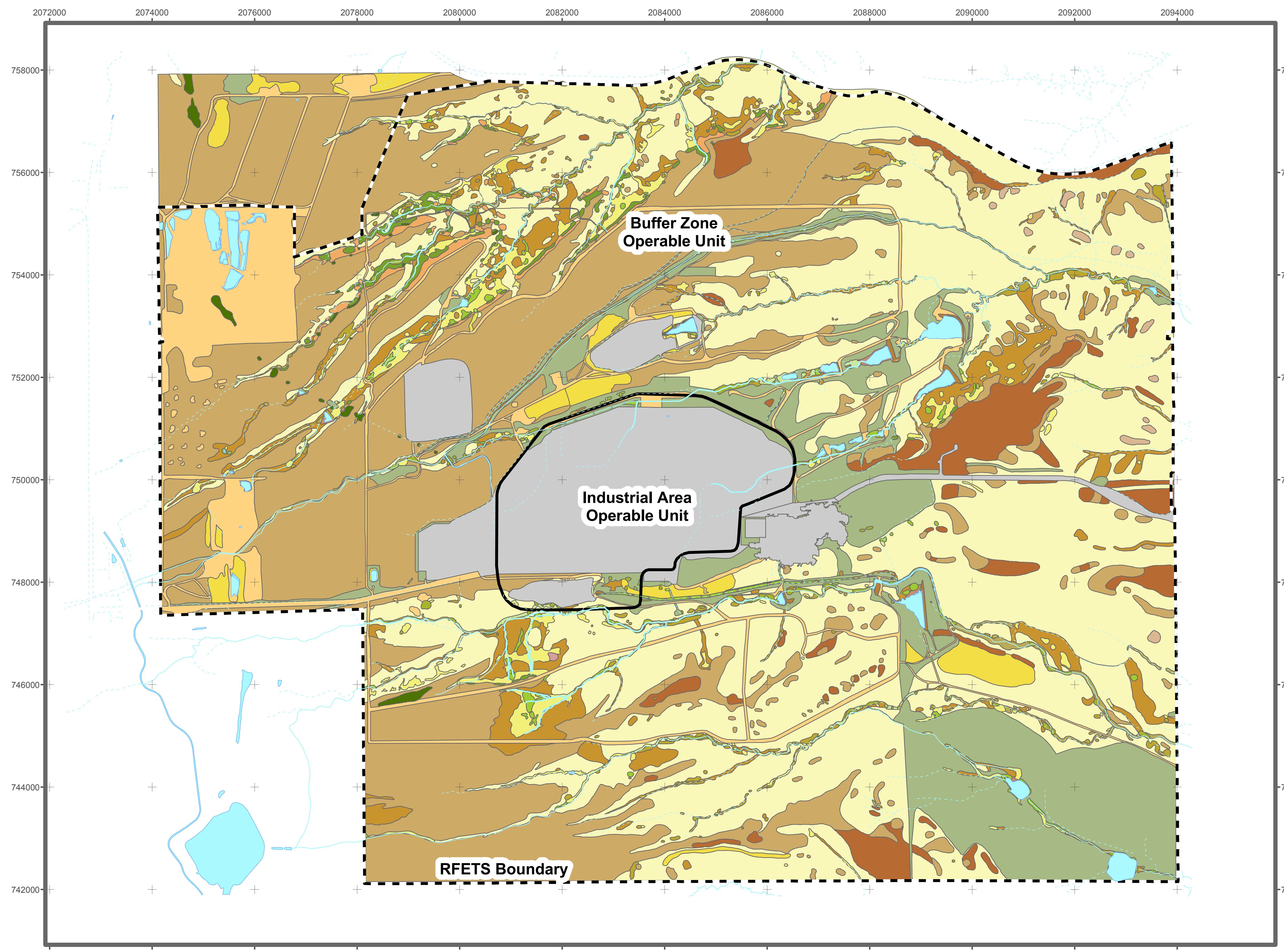


Figure 2.23

Rocky Flats Vegetation Map

KEY

DESCRIPTION

- Annual Grass/Forb Community
- Disturbed Areas
- Disturbed and Revegetated Areas
- Leadplant Riparian Shrubland
- Mesic Mixed Grassland
- Mudflats
- Open Water
- Ponderosa Woodland
- Reclaimed Mixed Grassland
- Riparian Woodland
- Riprap, Rock, and Gravel Piles
- Savannah Shrubland
- Short Grassland
- Short Marsh
- Short Upland Shrubland
- Tall Marsh
- Tall Upland Shrubland
- Tree Plantings
- Wet Meadow/Marsh Ecotone
- Willow Riparian Shrubland
- Xeric Needle and Thread Grass Prairie
- Xeric Tallgrass Prairie

Data Source:
Vegetarian map data provided by PTI Environmental Services Ecology

Note:
This map does not show all Federally designated wetlands. See the 1995 Site wetlands map prepared by the U.S. Army Corps of Engineers (USACE) for delineated wetland features.

Standard Map Features

- IA OU boundary
- Pond
- Site boundary
- Perennial stream
- Intermittent stream
- Ephemeral stream

N
W E
S

0 1,000 2,000
Feet

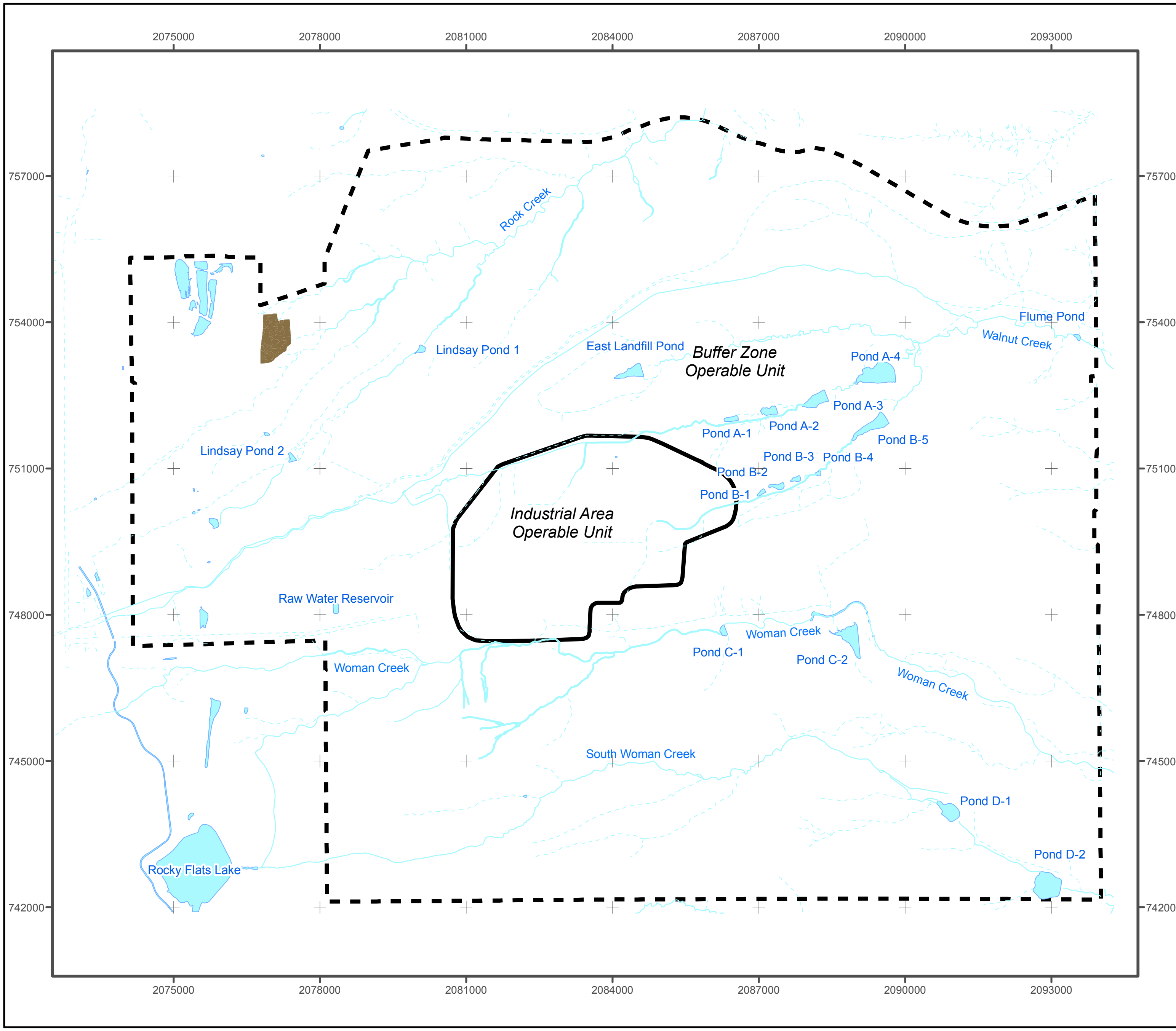
Scale 1:24,000

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD 27

U.S. Department of Energy
Rocky Flats Environmental Technology Site

File: W:\Projects\FY2005\RIFS_Fig\Sec02\ArcMap\Fig2_23_Vegetation.mxd

Figure 2.24
Windblown Sand
Deposition Area



KEY

Sand deposition area

Standard Map Features

IA OU boundary
Pond
Site boundary
Perennial stream
Intermittent stream
Ephemeral stream

N
W E
S

0 1,500 3,000
Feet

Scale 1:36,000

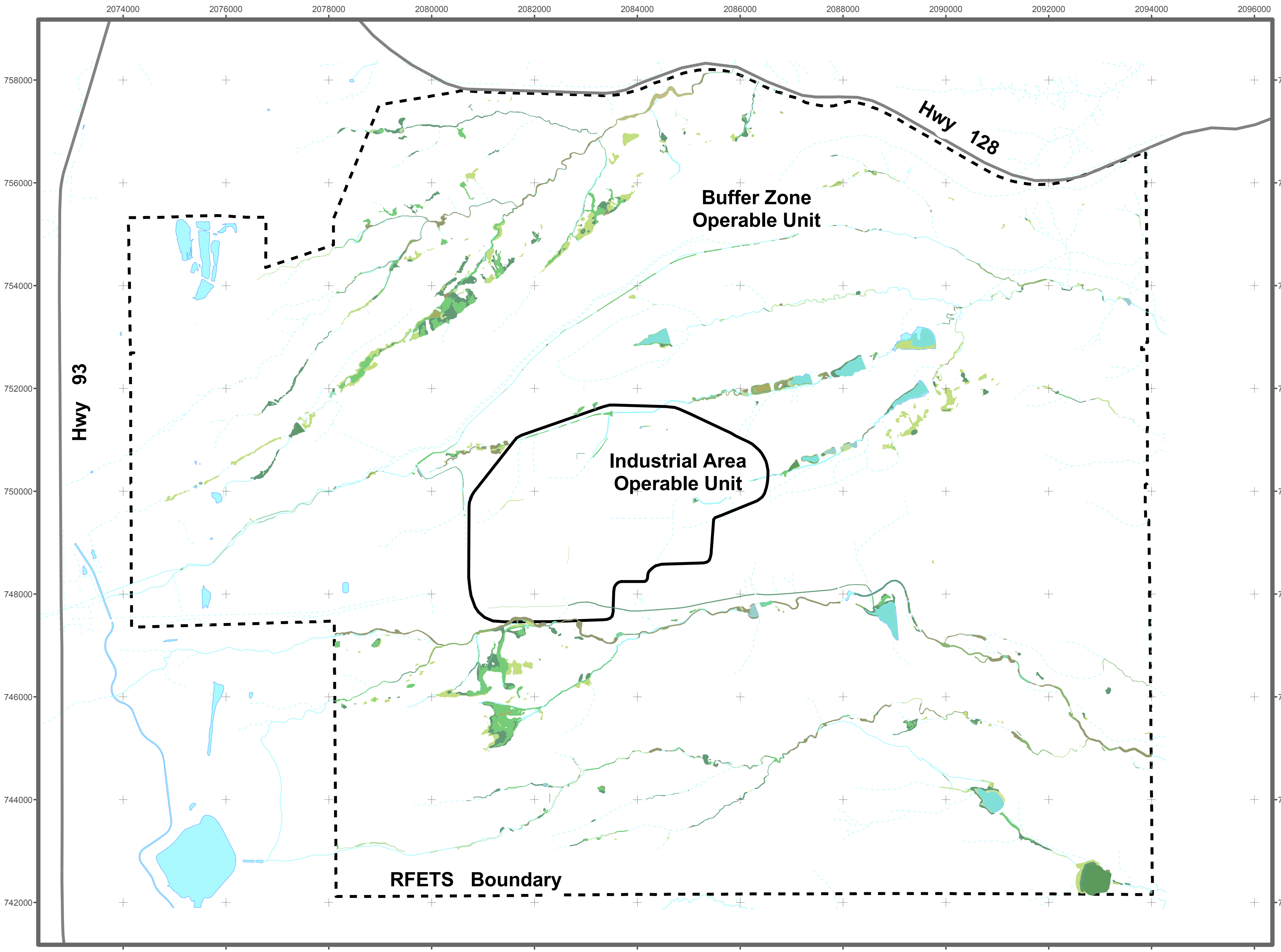
State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD 27

U.S. Department of Energy
Rocky Flats Environmental
Technology Site

File: W:\Projects\FY2005\RIFS_Fig\Sec02\
ArcMap\Fig2_24_WindblownSand.mxd

Figure 2.25

Wetlands



KEY

Wetland

- Lacustrine Limnetic, Unconsolidated Bottom, Permanently Flooded
- Palustrine Aquatic Bed, Permanently Flooded
- Palustrine Emergent, Saturated
- Palustrine Emergent, Seasonally Flooded
- Palustrine Emergent, Semipermanently Flooded
- Palustrine Emergent, Temporarily Flooded
- Palustrine Forested, Seasonally Flooded
- Palustrine Forested, Temporarily Flooded
- Palustrine Scrub-Shrub, Seasonally Flooded
- Palustrine Scrub-Shrub, Temporarily Flooded
- Palustrine Unconsolidated Bottom, Permanently Flooded
- Palustrine Unconsolidated Bottom, Semipermanently Flooded
- Palustrine Unconsolidated Shore, Seasonally Flooded
- Riverine Intermittent, Streambed, Intermittently Exposed
- Riverine Intermittent, Streambed, Intermittently Flooded
- Riverine Intermittent, Streambed, Seasonally Flooded

Standard Map Features

- IA OU boundary
- Pond
- Site boundary
- Perennial stream
- Intermittent stream
- Ephemeral stream

N W E S

0 1,000 2,000 Feet

Scale 1:24,000

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD 27

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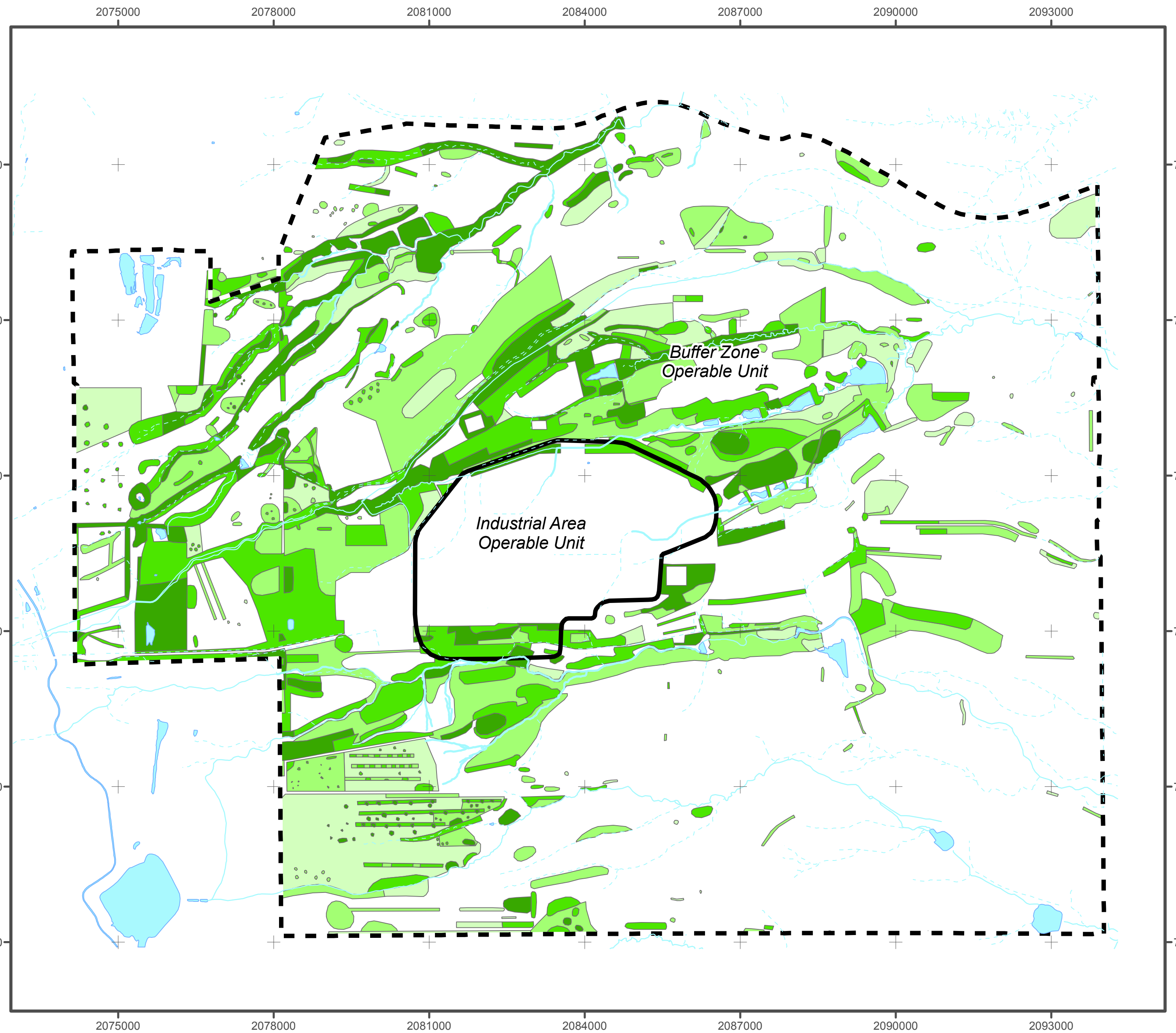

Figure 2.26
Diffuse Knapweed
(Centaurea diffusa) -
2001 Distribution

KEY

Diffuse Knapweed Distribution
- High density area
- Medium density area
- Low density area
- Scattered density area

Source Data:
K-H 2002c, 2001 Annual Vegetation Report for RFETS, May

Standard Map Features
- IA OU boundary
- Pond
- Site boundary
- Perennial stream
- Intermittent stream
- Ephemeral stream

N
W E
S

0 1,500 3,000 Feet

Scale 1:36,000

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD 27

U.S. Department of Energy
Rocky Flats Environmental
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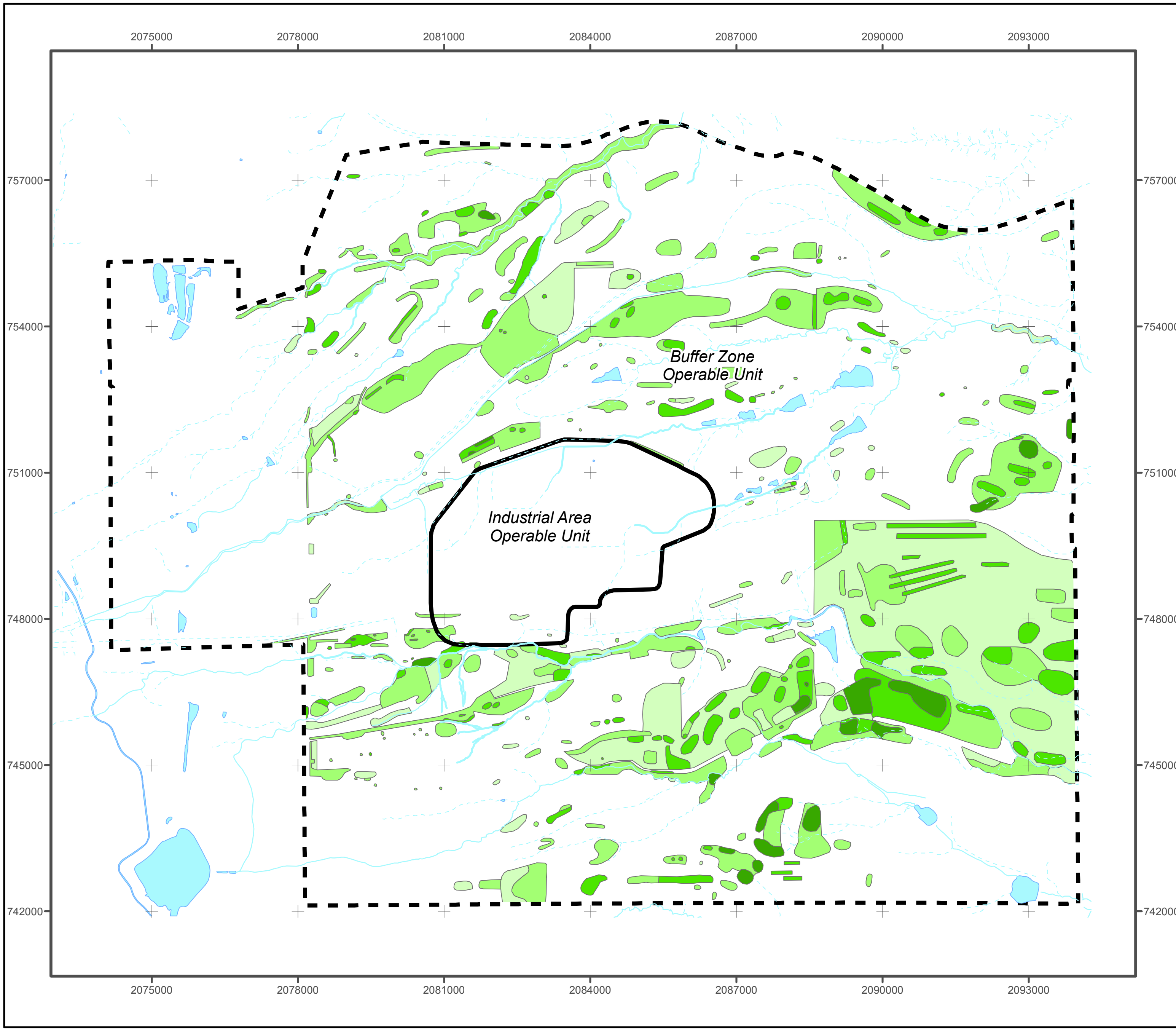

Figure 2.27
Common Mullein
(Verbascum thapsus) -
2001 Distribution

KEY

Common Mullein Distribution

- High density area
- Medium density area
- Low density area
- Scattered density area

Source Data:
K-H 2002c, 2001 Annual Vegetation Report for RFETS, May

Standard Map Features

- IA OU boundary
- Pond
- Site boundary
- Perennial stream
- Intermittent stream
- Ephemeral stream

N
W
E
S

0 1,500 3,000 Feet

Scale 1:36,000

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD 27

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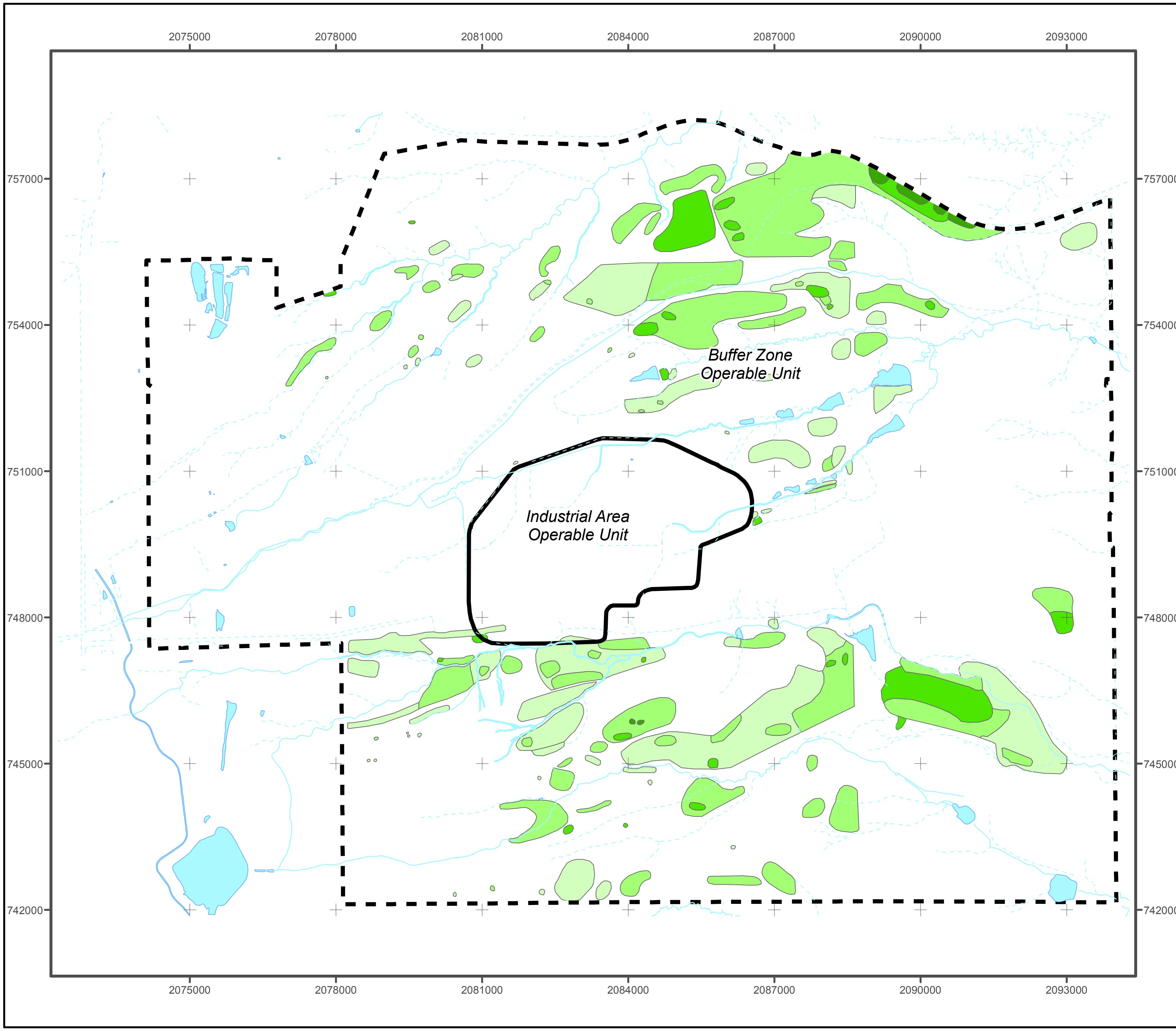

Figure 2.28
Musk Thistle
(Carduus nutans) -
2001 Distribution

KEY

Musk Thistle Distribution

- High density area
- Medium density area
- Low density area
- Scattered density area

Source Data:
K-H 2002c, 2001 Annual Vegetation Report for RFETS, May

Standard Map Features

- IA OU boundary
- Pond
- Site boundary
- Perennial stream
- Intermittent stream
- Ephemeral stream

N
W E
S

0 1,500 3,000 Feet

Scale 1:36,000

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD 27

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File: W:\Projects\FY2005\RIFS_Fig\Sec02\ArcMap\Fig2_28_MuskThistle.mxd

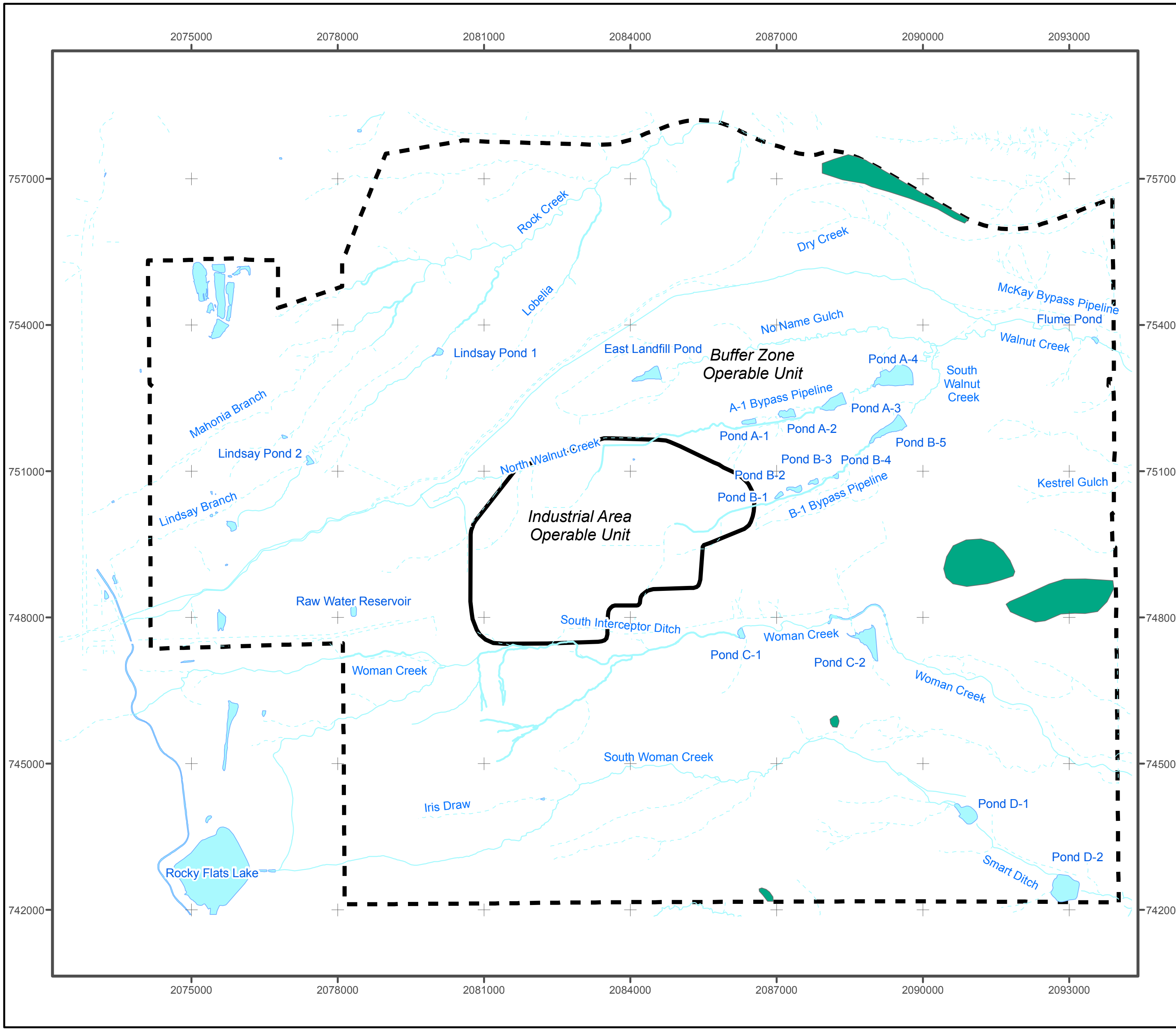

Figure 2.29
Prarie Dog Colonies

KEY

2004 prairie dog colonies

Data Source:
K-H, 2005b, 2004 Annual Ecology Report for the Rocky Flats Environmental Technology Site, prepared for Rocky Flats Field Office, Rocky Flats Environmental Technology Site, Golden, Colorado, June.

Standard Map Features

IA OU boundary
Pond
Site boundary
Perennial stream
Intermittent stream
Ephemeral stream

N
W E
S

0 1,500 3,000 Feet

Scale 1:36,000

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD 27

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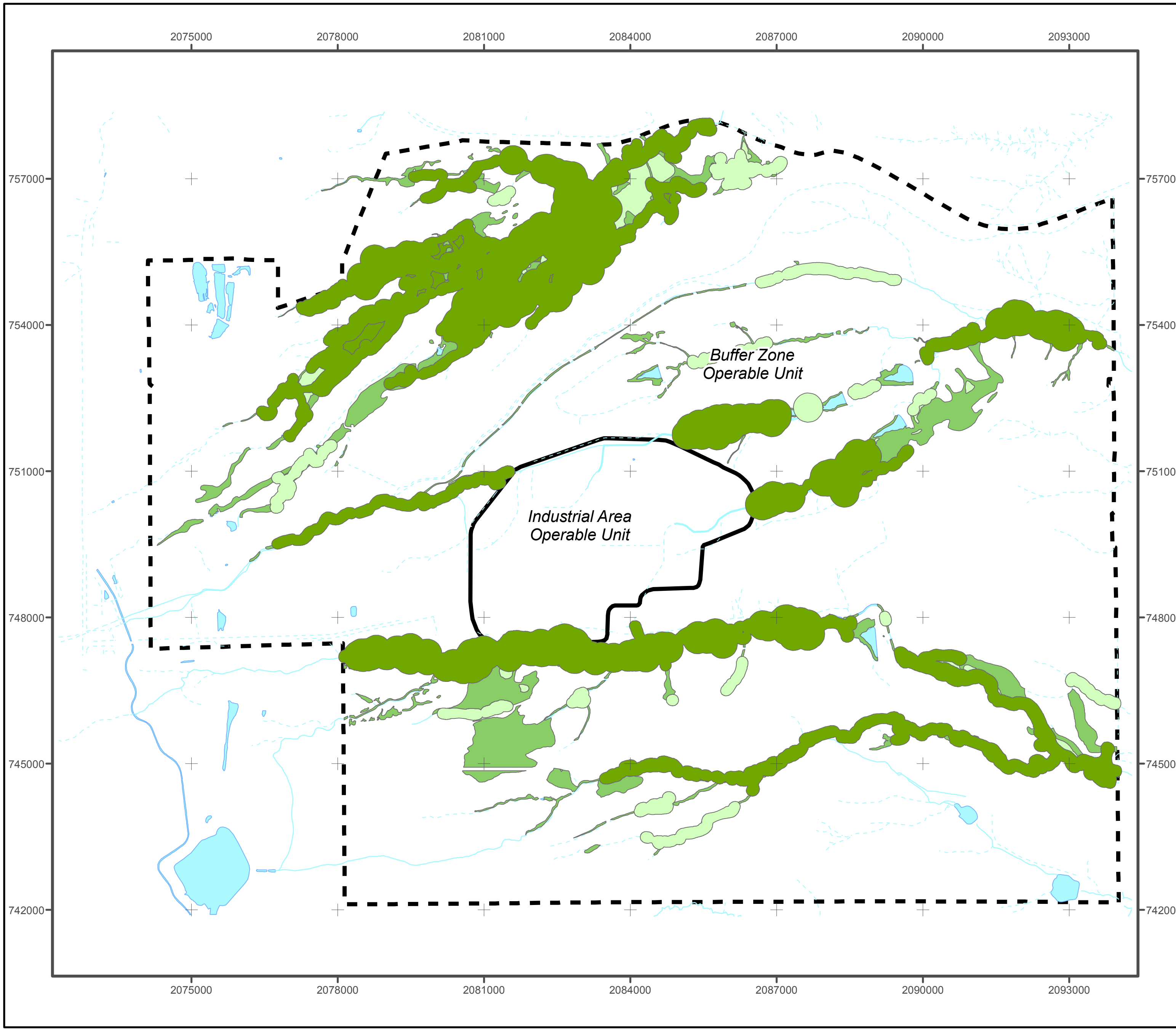

Figure 2.30
Preble's Meadow
Jumping Mouse (PMJM) Habitat

KEY

Habitat
- Protection area
- Contiguous wetlands
- Undefined PMJM area

Data Source:
DOE, 2004d, Programmatic Biological Assessment for the Department of Energy Activities at the Rocky Flats Environmental Technology Site, Part II, Revision 7, DOE, Rocky Flats Field Office, Golden, Colorado, April.

Standard Map Features
- IA OU boundary
- Pond
- Site boundary
- Perennial stream
- Intermittent stream
- Ephemeral stream

N
W E
S

0 1,500 3,000 Feet

Scale 1:36,000

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD 27

U.S. Department of Energy
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